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*Lockheed Aircraft Corporation*

**ADVANCED DEVELOPMENT PROJECTS**  
BURBANK, CALIFORNIA

REPORT NO. SP-665  
DATE 5-14-64  
COPY NO. # 6

**MODEL** A-12

**TITLE** LIGHTNING TESTS - MODEL A-12 PLASTIC RUDDER

STATINTL

PREPARED BY

REVIEWED BY

APPROVED BY

Advanced Development Projects

**REVISIONS**

DATE

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ABSTRACT

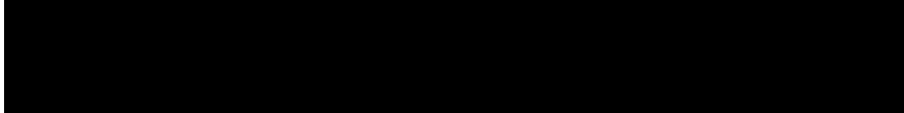
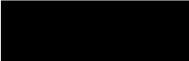
This report presents the results of lightning tests conducted on a Model A-12 airplane plastic rudder. The tests demonstrate that a simple segmented foil outside of the dielectric material provided adequate protection for almost any stroke energy level which might be encountered.

ACKNOWLEDGEMENT

The authors wish to acknowledge with appreciation the extra effort and spirit of cooperation of Messers.

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 in the performance of these lightning tests.

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OBJECT

To observe the effects of lightning strikes on the plastic rudder of a Model A-12 airplane. In addition, propose a practical means of enabling the rudder to sustain these lightning strikes with no/minimum damage.

CONCLUSIONS

It appears that the use of segmented foil mounted on the outside surface of the dielectric materials provides adequate protection for any stroke energy level that may be encountered. This was demonstrated in the second series of tests. The segmented foil type of arc shunt should be relatively easy to install and maintain. It should not compromise aircraft performance and need not appreciably degrade the performance of electronic equipment.

RECOMMENDATIONS

All exposed dielectric parts of the airplane should be considered as candidates for severe damage from lightning strikes. An estimate of their stroke termination probability should be attempted. Parts of the airplane that should be considered for protection are: Isolated nose sections (H.F. antenna exciter), nose radomes, plastic engine spikes, plastic fins, and possibly, plastic wing tip parts.

The arc shunts in each case should be approximately like those which were evaluated in the second series of tests. Detailed dimensions are not

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RECOMMENDATIONS (Continued)

critical; however, radical changes in size and/or spacing may need to be tested.

The arc shunt material must be as exposed to ambient air as is possible. A light coat (.001 inch) over the foil is permissible, but in no case can a thick coating of any dielectric material be used. The foil segments must be cemented to the outer surface; metallic fasteners of any sort must be avoided.

TEST SPECIMEN

The test article consisted of a complete rudder assembly (Serial No. 6) which had been subjected to structural tests at room and elevated temperatures, as well as room temperature internal pressure tests (see ADP Report SP-398). After the foregoing tests, the rudder was returned to the contractor for clean-up and retreatment of the surfaces to duplicate flight article requirements.

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Prior to shipment to the test activity, [REDACTED]

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[REDACTED] an inspection was made to locate and record areas of existing damage. Inspection of the left hand side (ref. Photo 1) revealed the following:

1. Areas 1, 2, 10, 11 and 12: Unbonded from core and substructure.  
The exact condition was not discernable.
2. Area 3: Delamination of skin.
3. Area 4: Scab on doubler apparently unbonded.

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TEST SPECIMEN (Continued)

4. Area 5: Unbonded.
  5. Areas 6, 7, 8 and 9: Heads of jo-bolts pulled out of substructure.
- Inspection of the right hand side (ref. Photo 2) revealed the following:
1. Areas 1, 2 and 3: Unbonded from core and substructure. The exact condition was not discernable.
  2. Area 4: Delamination of skin.
  3. Areas 5 and 6: Scab on doubler apparently unbonded.

TEST SET-UP AND PROCEDURE

The test article was mounted on a rudder post supported on a stub fin removed from the static test article. The gudgeon arm and actuator link were connected to the rudder. Except for the stand to support the stub fin, the rudder duplicated installation on a flight article.

Two series of tests were made, the first on 11 April 1964 and the second on the 25th of April 1964. The first series of lightning tests ran to a maximum intensity of approximately five million volts at thirty thousand eight hundred amperes. The second series of tests utilized higher currents (maximum of about 200,000 amperes) at lower voltages (approximately 150,000 volts).

In the first series of tests the discharge electrode was approximately twelve feet above the rudder. Three basic chordwise locations were used; aft, center, and forward. In the aft position the electrode was above the tip trailing edge portion of the rudder. The center position had the electrode approximately midway between the tip leading and trailing edges. The

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TEST SET-UP AND PROCEDURE (Continued)

forward location had the electrode above the most forward edge of the stub fin and still about twelve feet above the rudder tip.

Included in the first series of tests were some side shots. The electrode about seven feet above the floor and approximately eight feet from the rudder plane. Two chordwise positions were used. In the forward position, the electrode was located midway between the post and leading edge areas. In the aft position, the electrode was located midway between the post and the trailing edge areas.

In the second series of tests two basic electrode positions, forward and aft, were used. In each position the electrode was placed approximately 1/4 inch away from either the rudder tip leading or trailing edge.

For the high current tests, local portions of the leading edge were used.

TEST RESULTS

Test results are summarized in Tables I and II and in photographs of the various test runs.

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Based on these results of the tests conducted at the [REDACTED]

[REDACTED] it appears that lightning damage to vulnerable components may be prevented quite easily if proper protection is provided.

RUN NO.	BOLT INTENSITY		O.H. ELEC. POSIT		HIT LOCAT TIP		REMARKS
	MILOVOLTS	KILOAMPS	FWD	AFT	FWD	AFT	
A	3060	113		✓		✓	TRIAL RUN. GROUNDING WIRE ON PERIPHERY OF RUDDER.
I	↑	↑		✓		✓	SAME AS A
II				✓		✓	SAME AS A
III				✓		✓	GROUNDING WIRE REMOVED. ARC TRAVELLED INTERNALLY TO GROUND.
IV				✓		✓	SAME AS III
V				✓		✓	RUDDER T.E. DEFL LEFT RESULTS SAME AS III
VI				✓		✓	T.E. DEFL LEFT. RESCON TAPED ON TIP T.E. ARC PUNCTURED RESCON AND TRAVELLED INTERNALLY TO GROUND.
VII			CENTERED		✓		NEW RESCON PUT ON TIP L.E. AND T.E. SAME RESULT AS II
VIII			↑		✓		ALUMINUM FOIL USED IN PLACE OF RESCON. ARC TRAVELLED INTERNALLY TO GROUND.
IX		.113	↓				L.E. AND T.E. FOLDS INTERCONNECTED WITH COPPER WIRE WHICH WAS GROUND TO AFT SEMI-CONDUCTOR STRIP. PHOTOS SHOW LIGHT STREAMERS FROM WIRE OTHERWISE NO CHANGE IN RESULTS.
X		NO RDG	CENTERED				REMOVED ALUMINUM FOIL FROM TIP L.E. AND T.E. COPPER WIRE RAN FROM VERTICAL SEMI-CONDUCTOR STRIP TO WITHIN ONE FOOT OF L.E. ON TIP OF RUDDER EXCEPT FOR CLEARER STREAMER DEFINITION RESULTS SAME.
XI					✓		ALUMINUM FOIL CORNERS INSTALLED COPPER WIRE FROM X RETAINED. ARC TRAVELLED INTERNALLY.
XII			SIDE				SIDE SHOT ELECTRODE 83 INCHES FROM FLOOR AND 3 FEET FROM MID CHORD OF RUDDER ARC APPEARED TO STRIKE RUDDER SLIGHTLY ABOVE AND AFT OF POST WIRE AND FOIL SAME AS X
XIII				SIDE		✓	ARC STRUCK TIP T.E. AND APPEARED TO TRAVEL DOWN T.E. BEFORE DISAPPEARING INTERNALLY.
XIV				SIDE		✓	1 INCH LONG COPPER WIRES AT 1 1/8 INCH WERE TAPED AROUND PERIPHERY OF RUDDER. COPPER WIRE INTERCONNECTING L.E. AND T.E. STRIPS TAPED ALONG BOTTOM OF RUDDER. SLIGHT GLOW AT ENDS OF WIRES WHEN STRUCK BY ARC. SUBSEQUENT TEST RUN WITH COPPER "NEEDLES"
XV			SIDE		✓		ARC STRUCK TOP OF RUDDER INSTEAD OF POST AREA. FAINT GLOW AT ENDS OF SOME "NEEDLES"
XVI			✓		✓		PHOTOS REVEALED SLIGHT GLOW AT ENDS OF "NEEDLES" ALONG TOP AND L.E. OF RUDDER
XVII			CENTERED		✓		SAME AS XVI
XVIII		NO RDG		✓		✓	SAME AS XVII EXCEPT GLOW ALONG T.E.
XIX A		.494		✓		✓	GLOW ALONG T.E. AND TOP
XIX B		.494		✓		✓	NO GLOW. MISSING "NEEDLES" ON TOP WERE REPLACED.
XIX C		.494		✓		✓	SAME AS XIX A
XX		.494	✓		✓		PHOTOS SHOW ARC TRAVELLING ALONG L.E.
XXI		3.10	✓		✓		SAME AS XX SIGNS OF SCORCHING IN GAP BETWEEN "NEEDLES" DISCOLORATION EASILY REMOVED WITH PENCIL ERASER. LOOSE NEEDLES RETAPED
XXII	↑	3.10		✓		✓	SAME AS XXI
XXIII	3060	21.20		✓		✓	SAME AS XXII NO VISIBLE DAMAGE. ODOR DETECTED. EVIDENCE OF BURNING OF TIP AT ENDS OF NEEDLES. LOOSE AND MISSING NEEDLES REPLACED.
XXIV	4386	30.8	✓		✓		PRIMARY PATH OF ARC ALONG L.E.
XXV	↑	↑		✓		✓	ARC TRAVELLED AROUND RUDDER SLIGHT SCORCHING ON TOP SURFACE AT ENDS OF NEEDLES.
XXVI	↑	↑		✓		✓	RUDDER T.E. DEFLATED LEFT. RESULTS SAME AS XXV.
XXVI A	4386	30.8		✓		✓	RESULTS SAME AS XXVI
XXVII	2193	15.7		✓		✓	REMOVED NEEDLES FOR REMAINING TESTS. TIP T.E. OPERATED BY ARC. TRACKING ON TOP
XXVIII	4386	30.8	✓		✓		TRACKING ON TOP FORWARD.
XXIX	4386	30.8	✓				RE-RUN SAME RESULTS.
XXX	4386	30.3		✓		✓	1/2 IN. DIA PATCH PLANNED OFF SOME SMOKE FROM PATCH AREA. SLOWLY TURNING RUDDER. ROTATES FREELY.
XXXI	4386	30.8		✓		✓	STUB PIN T.E. RUDDER T.E. TRACKING ON TOP FORWARD TO DETECT DISCOLORATION.

Approved For Release 2000/04/12 : CIA-RDP67B00657R000100010001-8

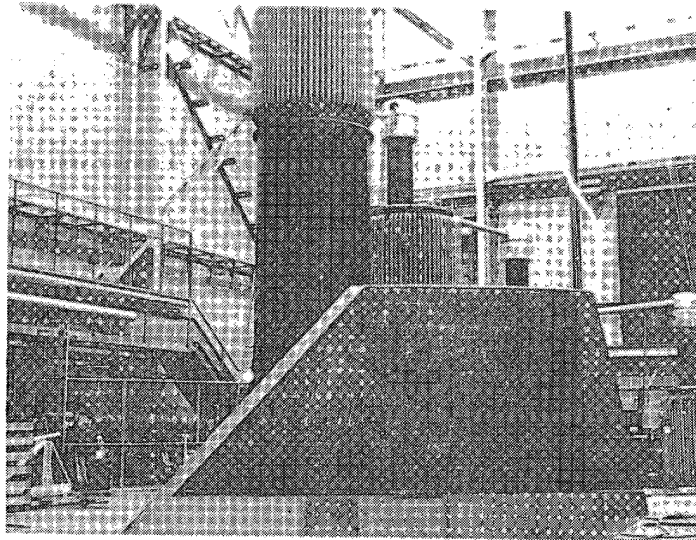


Photo A-1 Trial run with copper grounding wire around periphery of rudder.

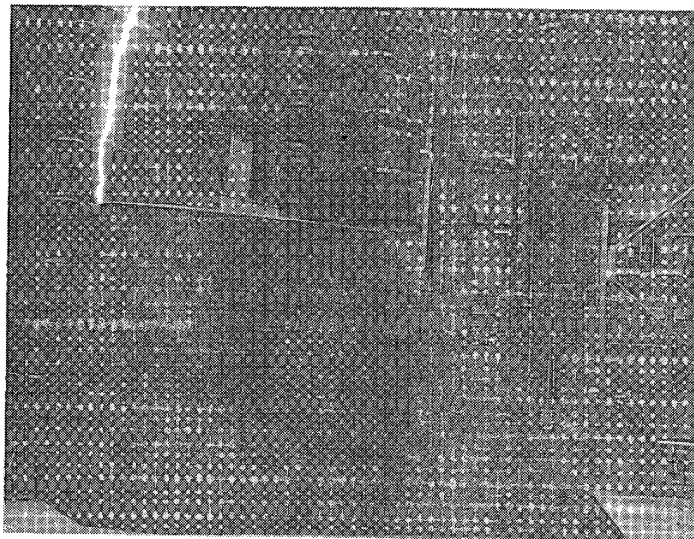


Photo I-1 R.H. side of rudder at second trial run with copper grounding wire around periphery of rudder.

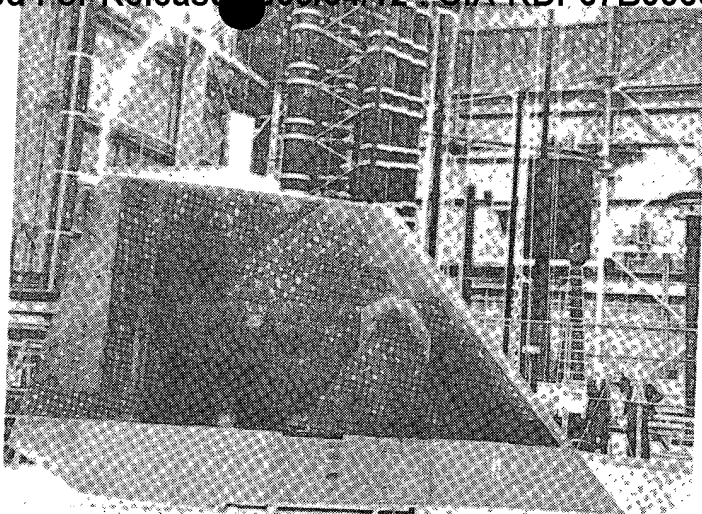


Photo II-1 Run II Test or sample run with copper grounding wire around periphery of rudder.

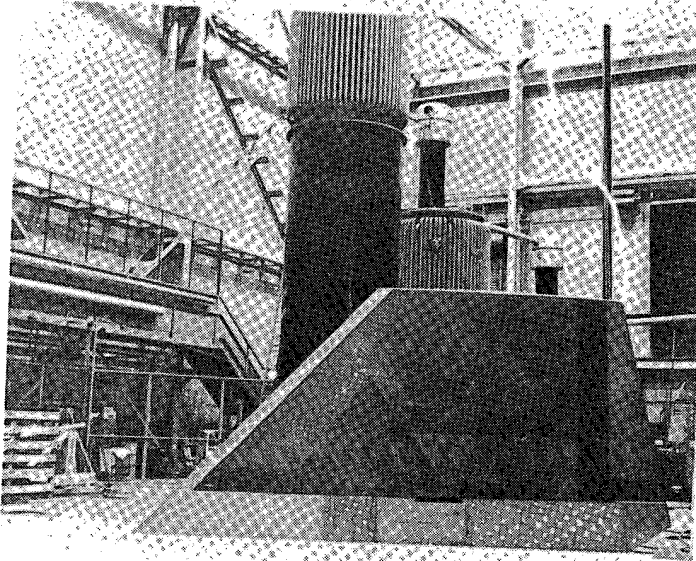


Photo II-2 L.H. side during trial run.

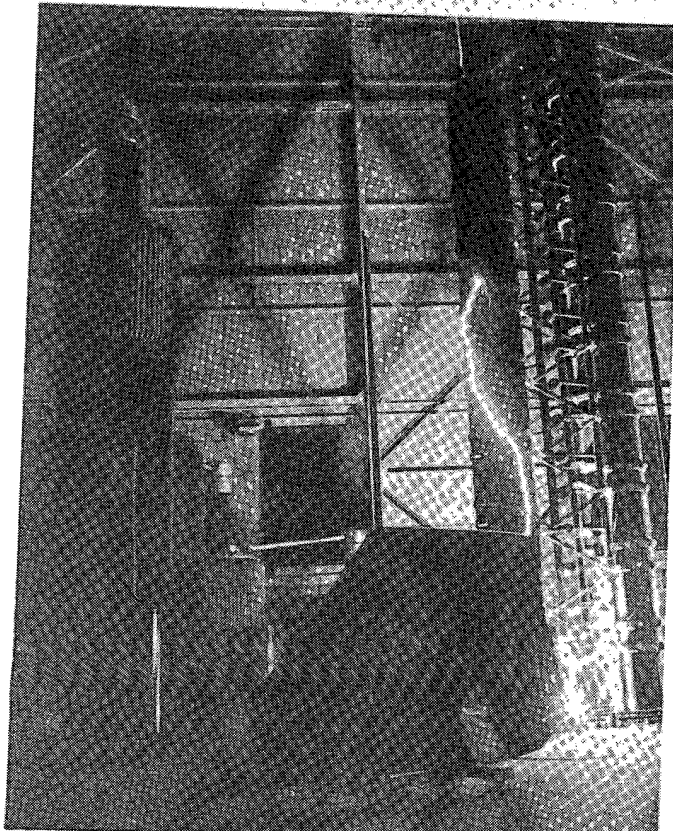


Photo II-3 Trial run. Note location of electrode.

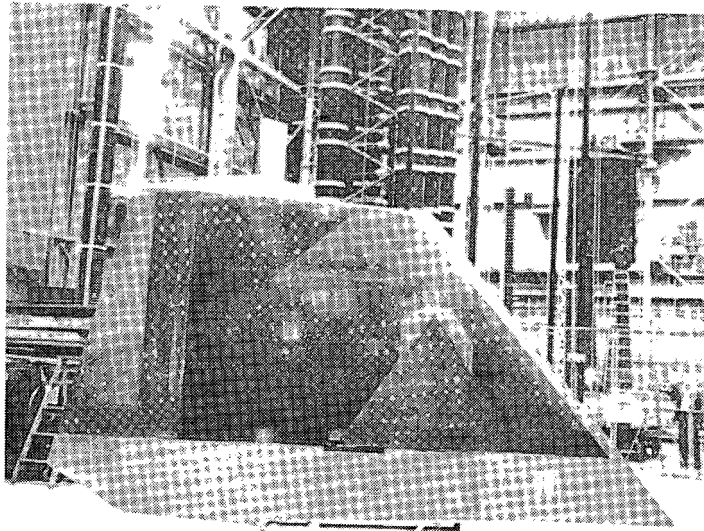


Photo III-1 Run III with copper grounding wire removed. Note that arc has entered rudder and followed an internal path to ground.

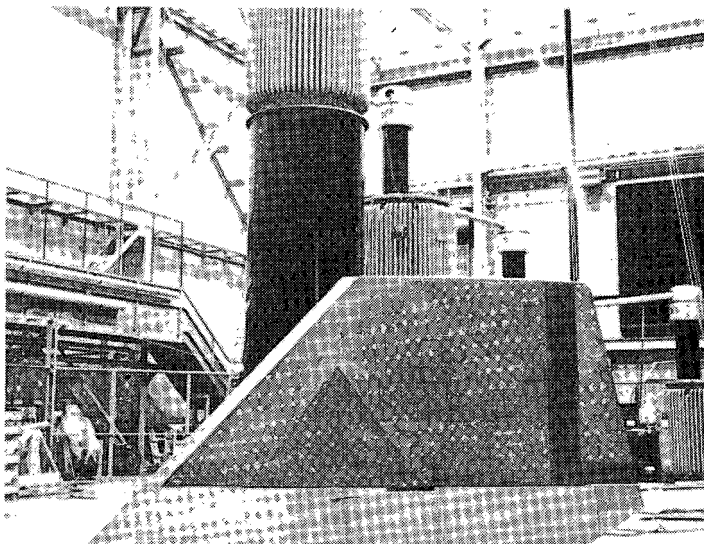


Photo III-2 Run III L.H. side.

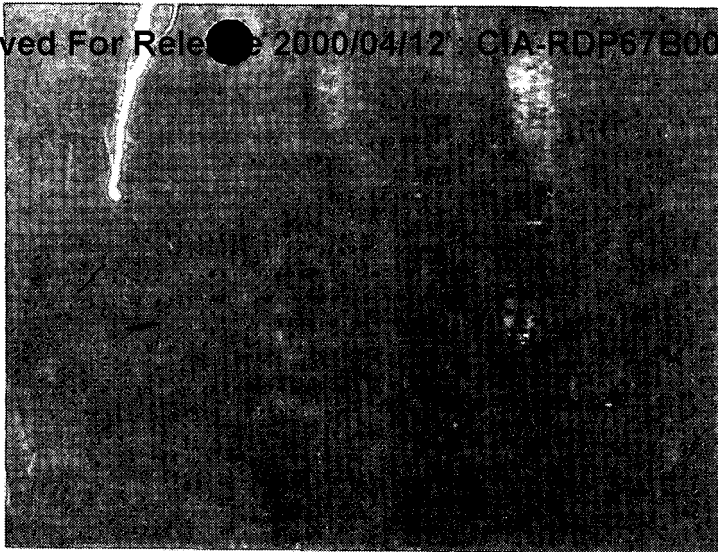


Photo IV-1 Run IV with copper grounding wire removed. R.H. view.

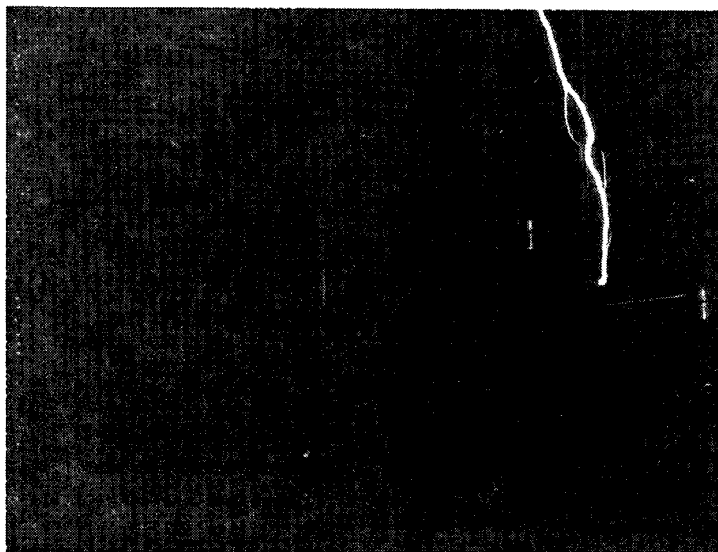


Photo IV-2 Same as above except L.H. side.

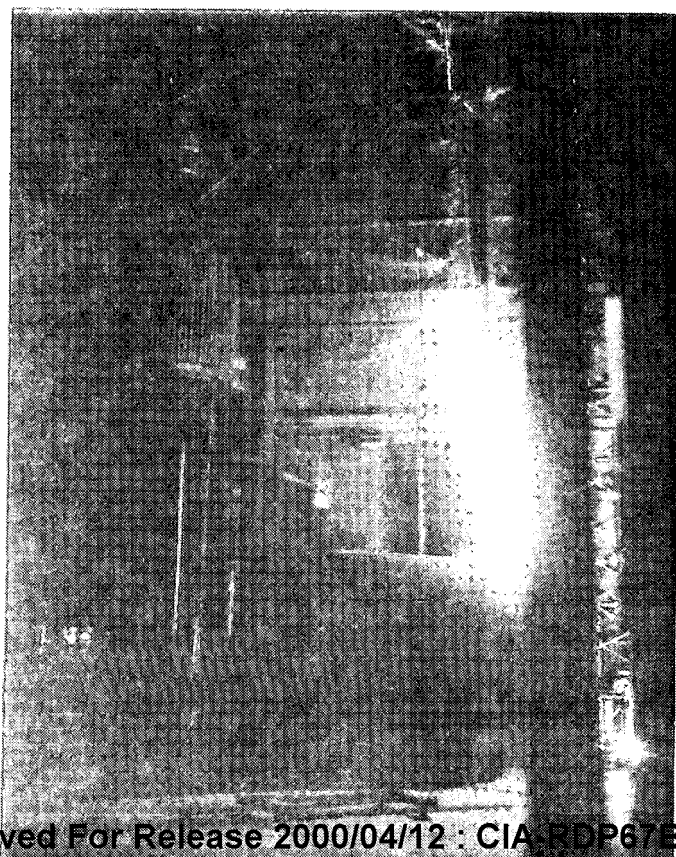


Photo IV-3 Run IV is similar to Run III. Again arc moves along an internal path to ground which could mean potential damage.

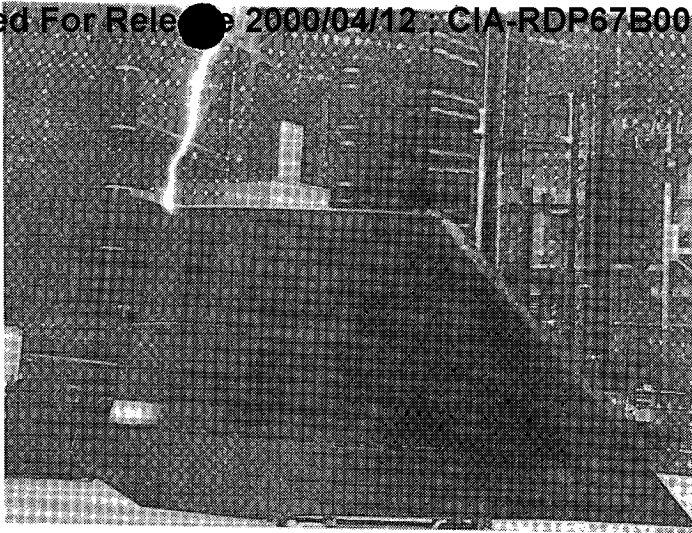


Photo V-1 Run V-Rudder  
Deflected T.E. Left.

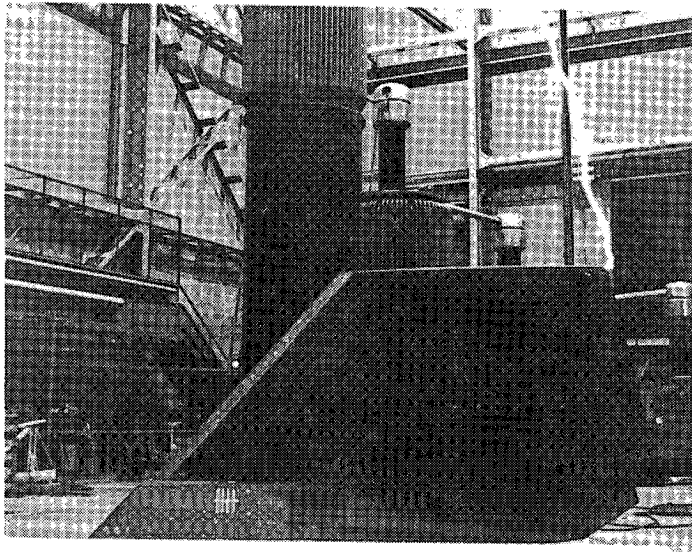


Photo V-2 Run V  
Results are similar  
to Runs III and IV.

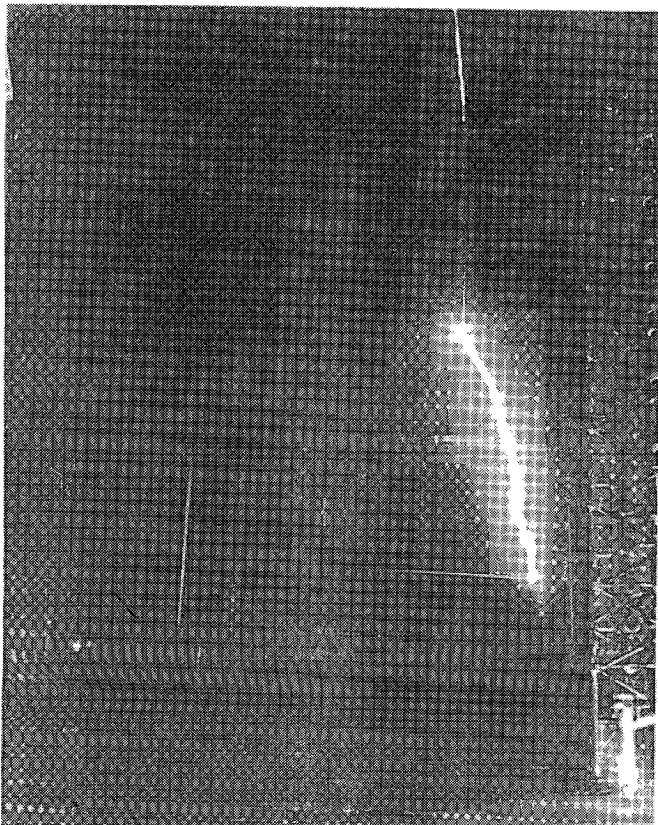


Photo V-3.



Photo VI-1. Run VI  
Small Piece of Rescon  
on T.E. corner. Rudder  
deflected.

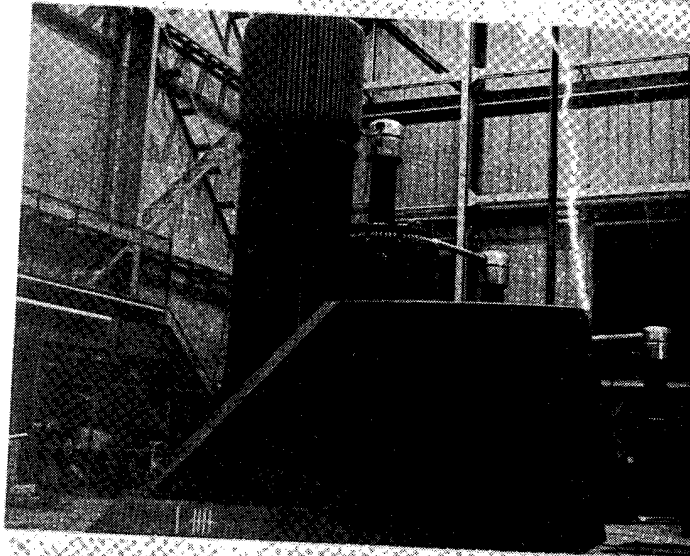


Photo VI-2. Note small  
glow down along T.E.  
Arc seems to be entering  
rudder along T.E.



Photo VI-3. Run VI.  
Examination after run  
revealed small puncture  
through Rescon.

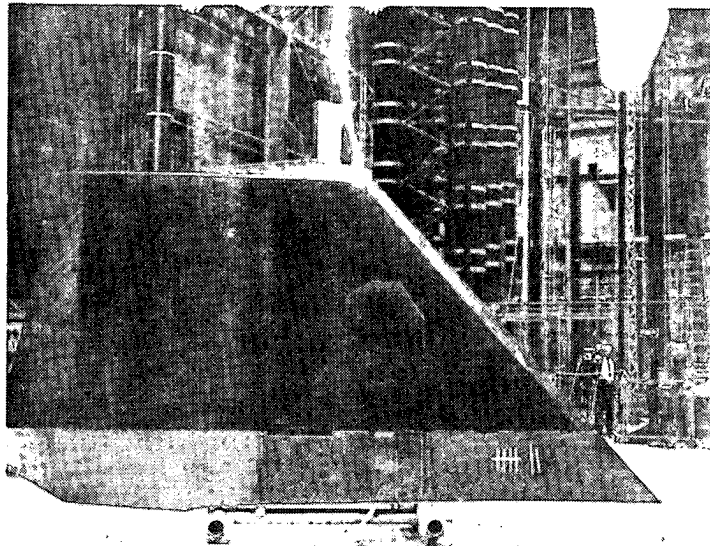


Photo VII-1. Run VII. Electrode in Center Position. Reson on Rudder Tip Corners.

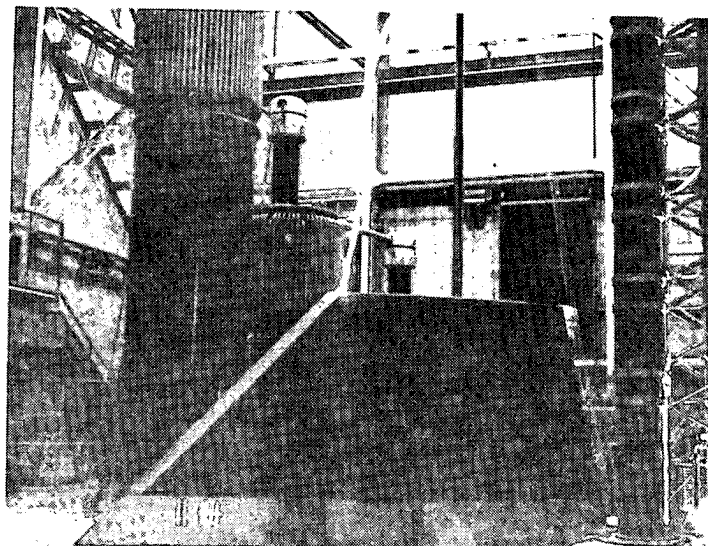


Photo VII-2. Run VII. L.H. Side

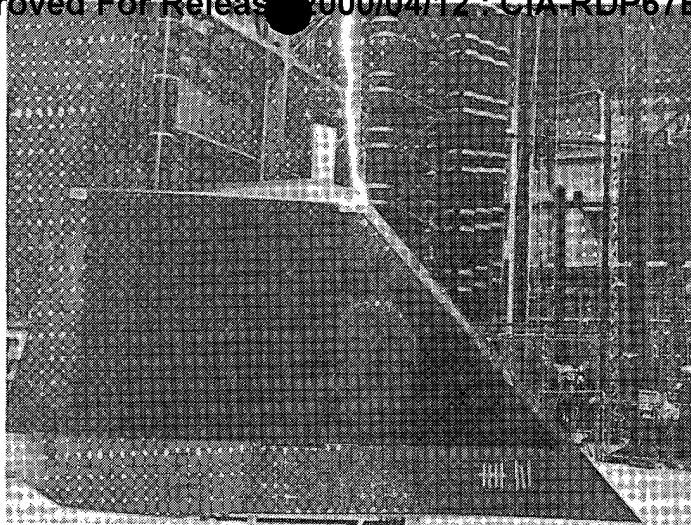


Photo VIII-1. Run VIII.  
Aluminum Foil Installed  
L.E. and T.E. Electrode  
in center position.

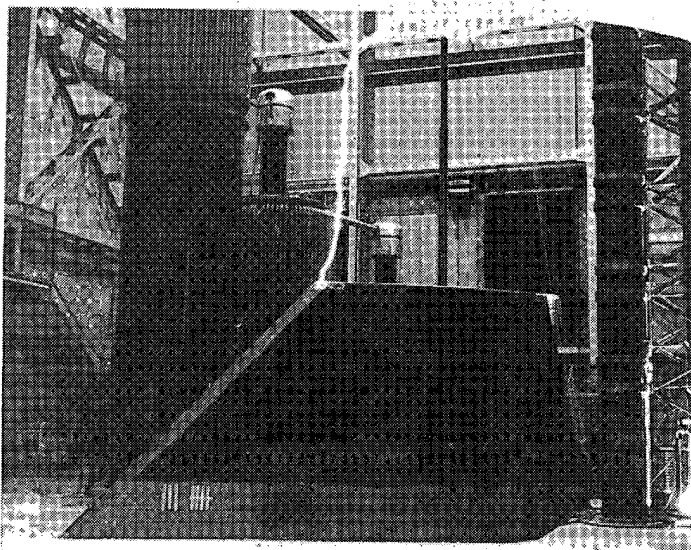


Photo VIII-2.

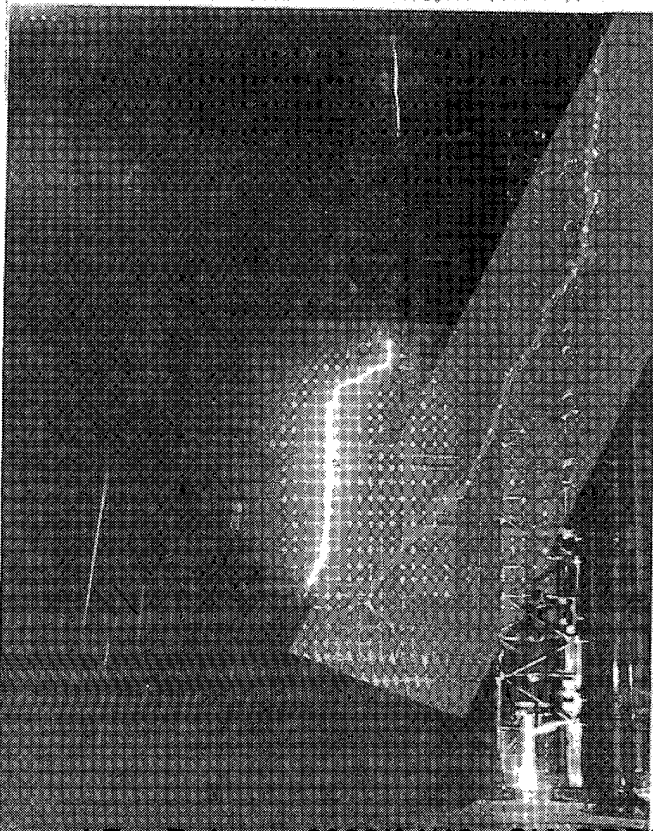


Photo VIII-3.

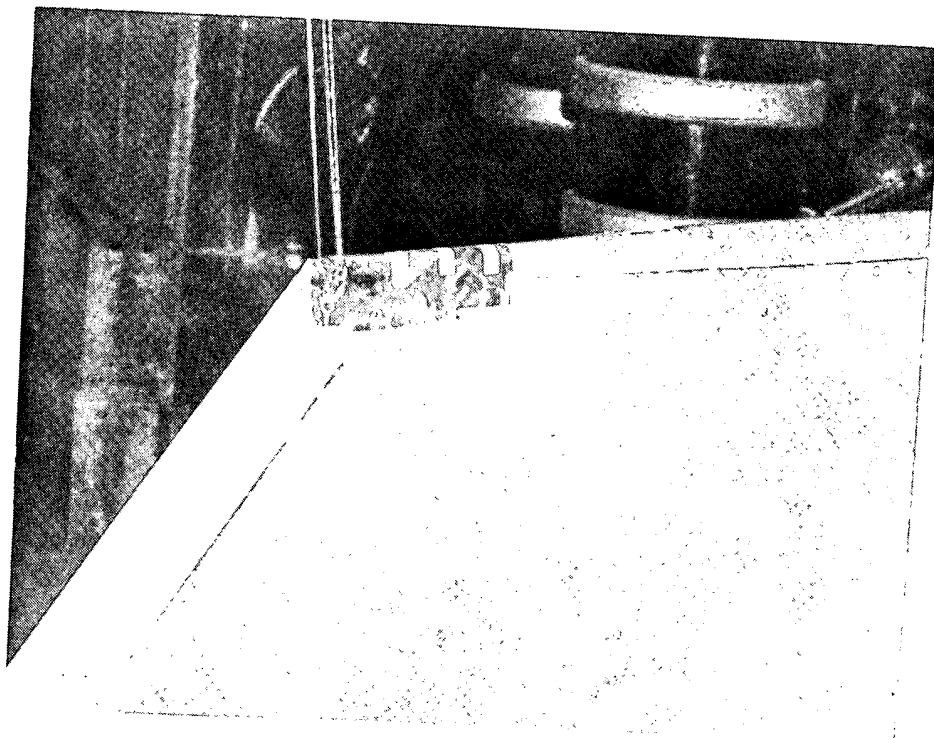


Photo VIII-4. Aluminum Foil on L.E. Rudder Tip as Tried in Run No. VIII.



Photo VIII-5. Aluminum Foil on T.E. Rudder Tip as Tried in Run No. VIII.

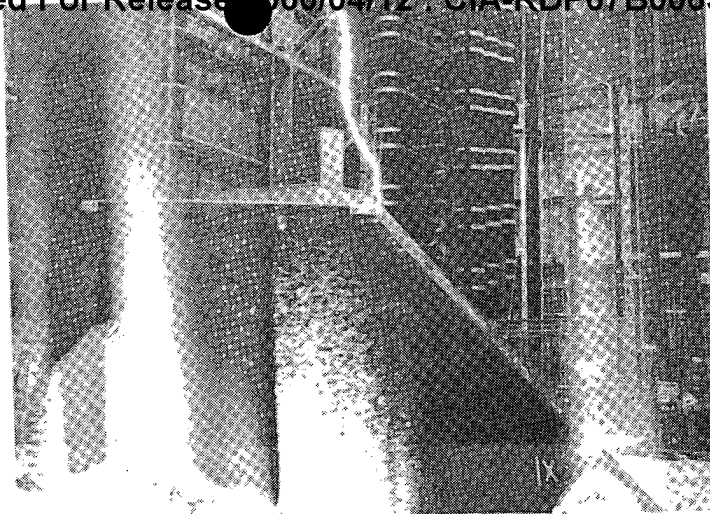


Photo IX-1. Run IX  
Aluminum Foil plus Copper  
Wire on Trip. Electrode  
in Center Position.

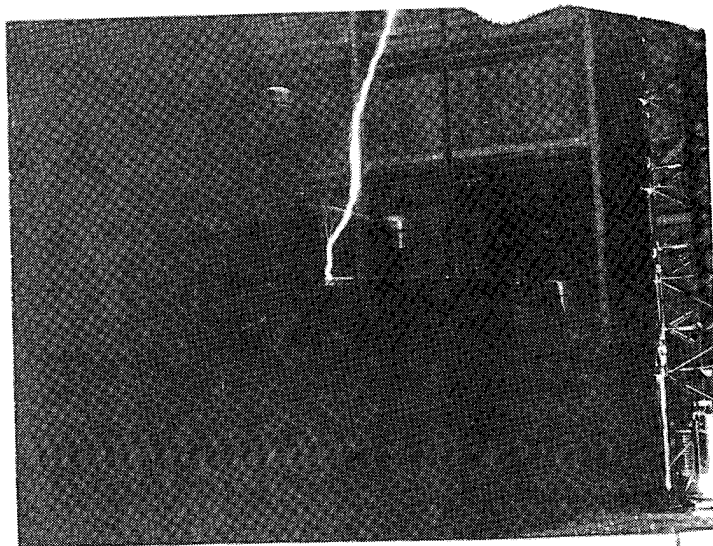


Photo IX-2.

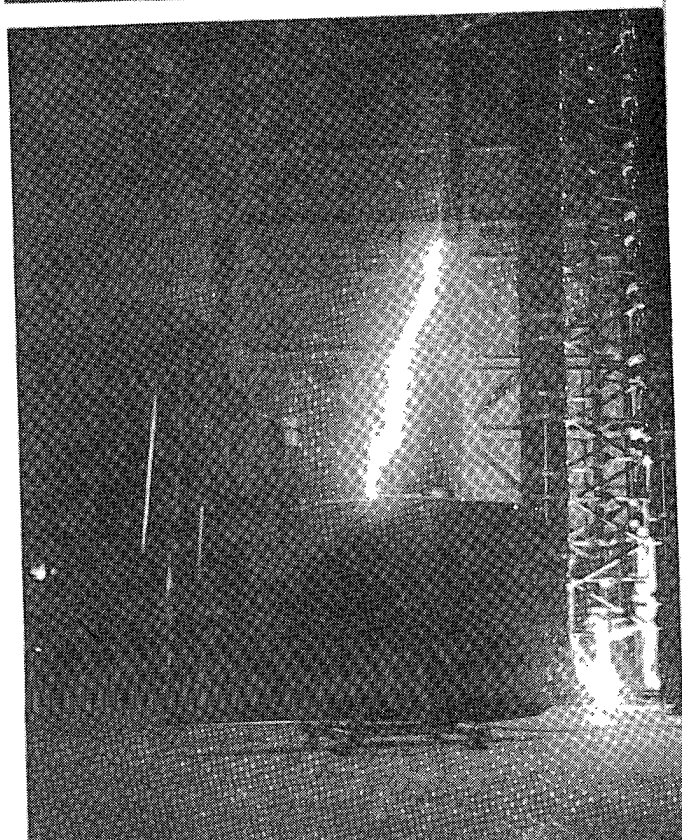


Photo IX-3. Note  
trace of streamers  
at top of rudder.

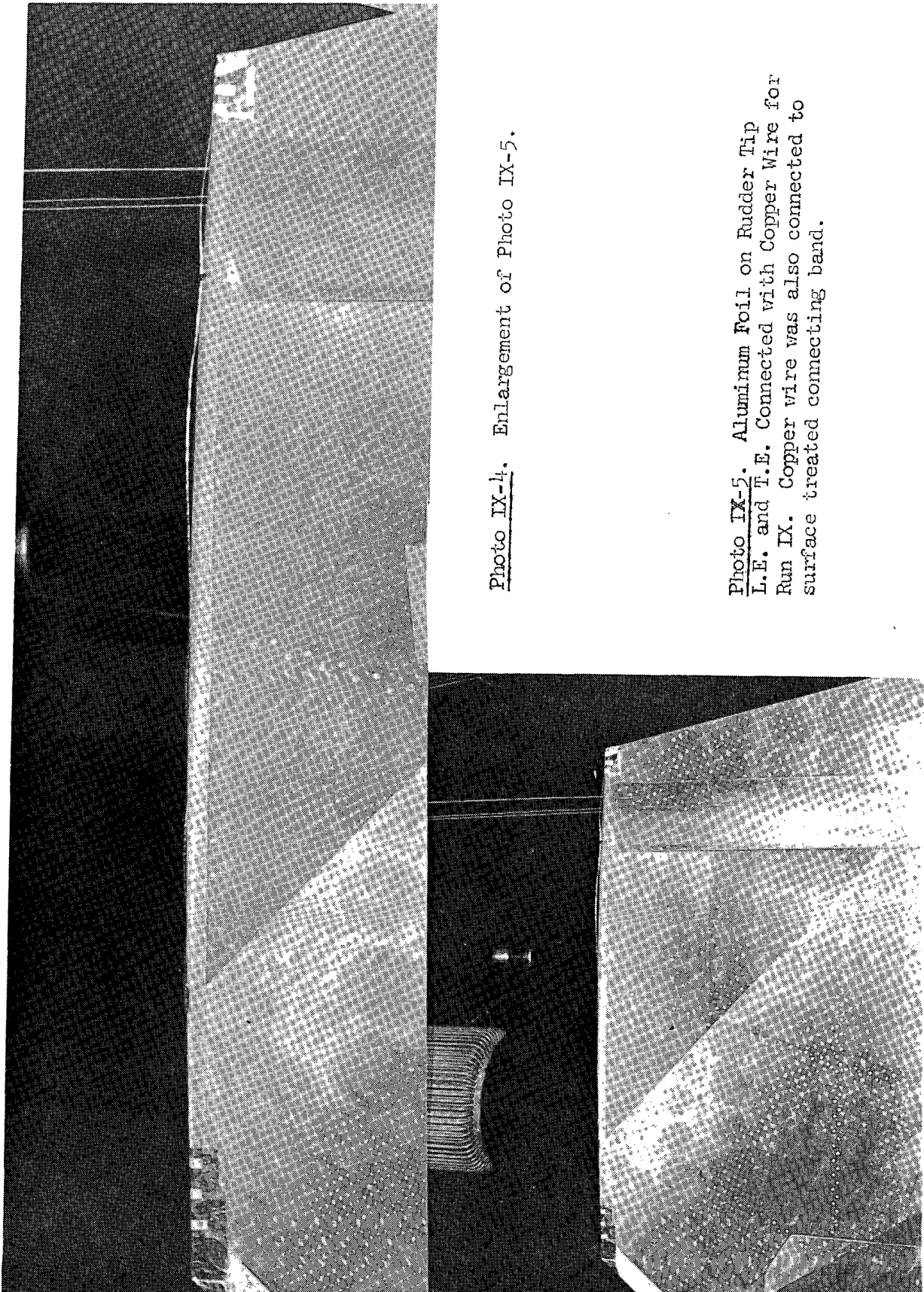


Photo IX-4. Enlargement of Photo IX-5.

Photo IX-5. Aluminum Foil on Rudder Tip  
L.E. and T.E. Connected with Copper Wire for  
Run IX. Copper wire was also connected to  
surface treated connecting band.

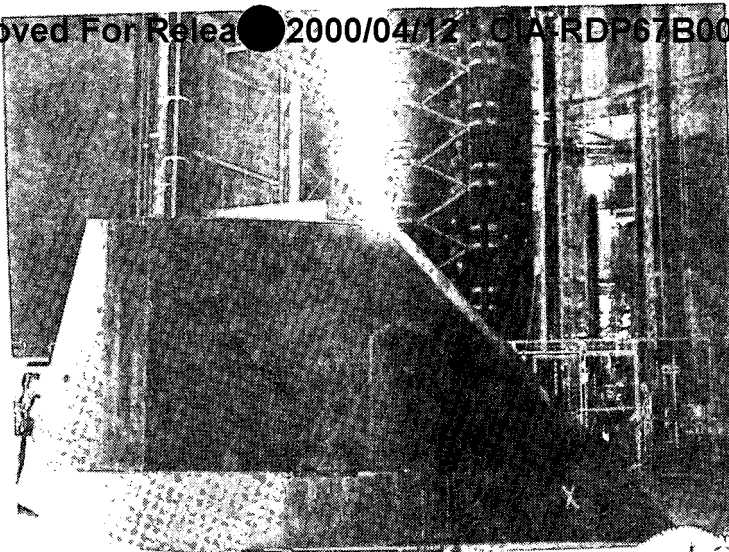


Photo X-1. Run X.  
Aluminum Foil Removed.  
Short copper lead on  
tip. Note streamers  
along top of rudder.

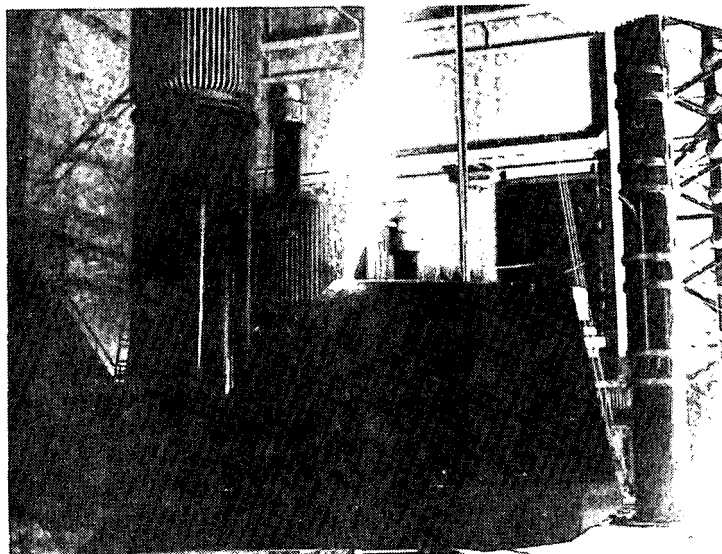


Photo X-2.

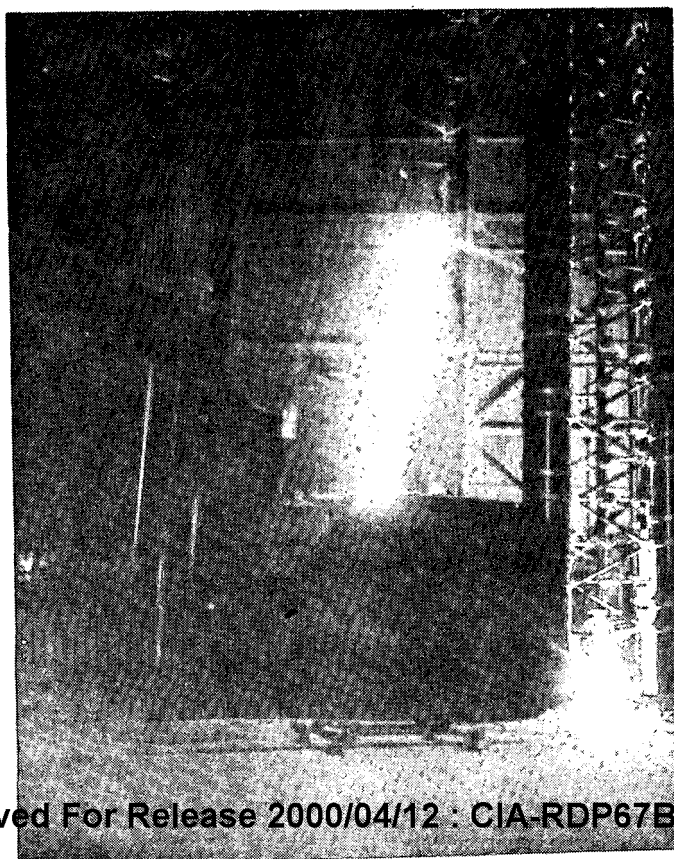


Photo X-3.



Photo XI-1. Run XI. Aluminum Caps on  
and short copper lead from Run X retained.  
Forward electrode location.

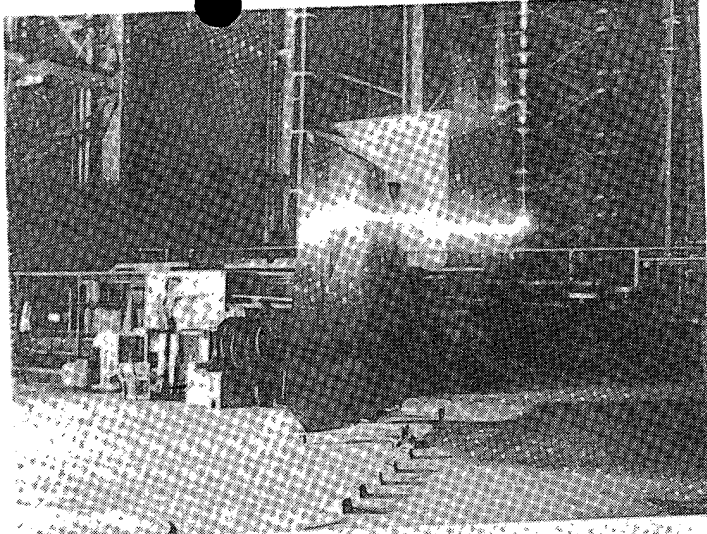


Photo XII-1. Run XII.  
Forward side discharge.  
Aluminum caps and copper  
wire as in Run XI.

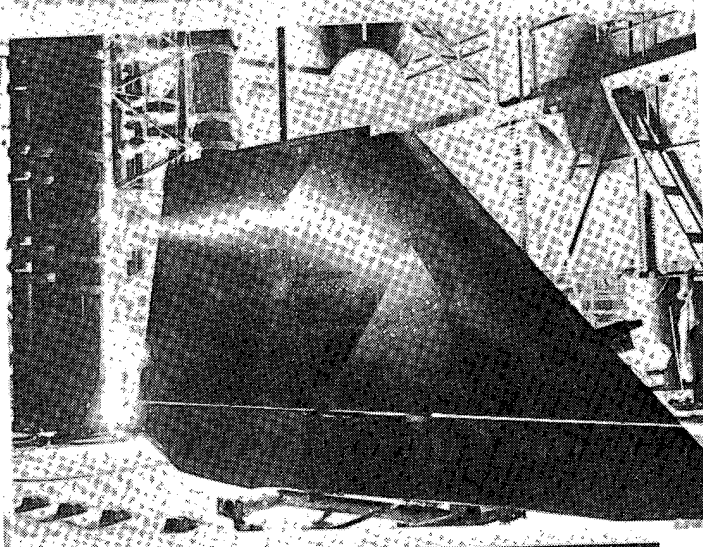


Photo XII-2.

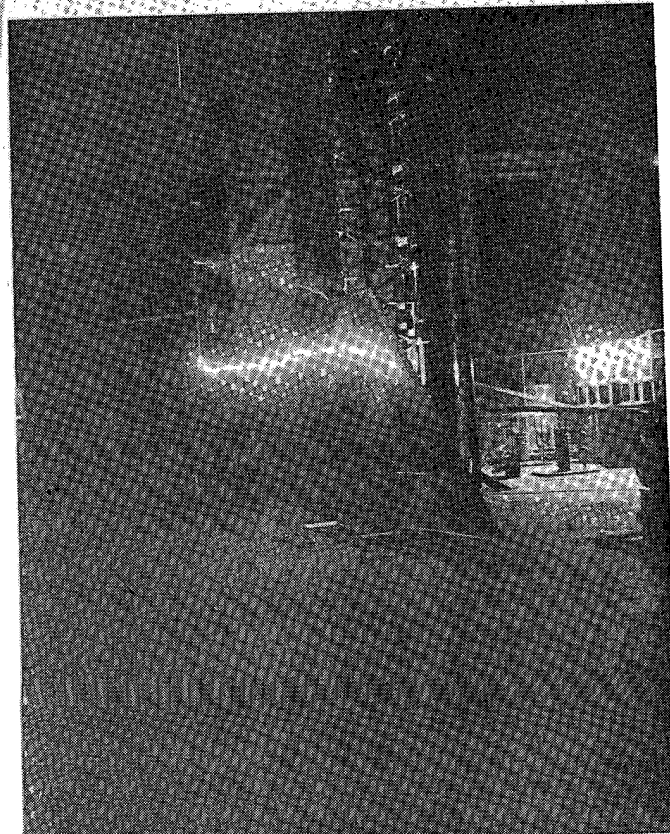


Photo XII-3. Run XII.  
Note streamer from top  
of rudder and electrode.

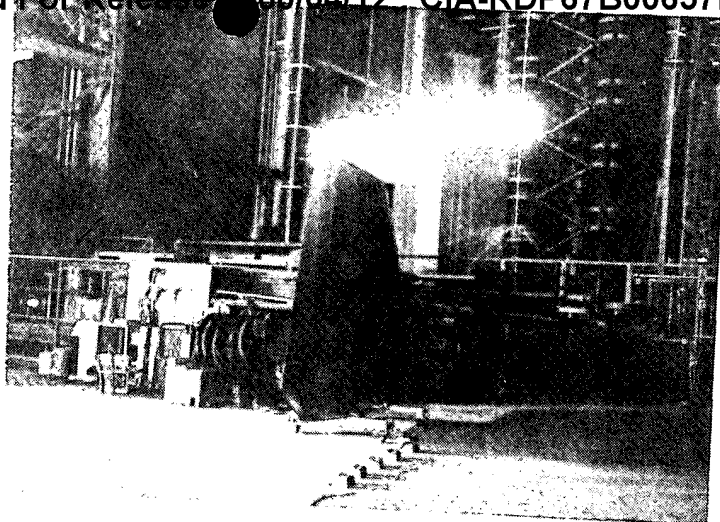


Photo XIII-1. Run XIII.  
Aft side discharge.  
Aluminum caps and copper  
wire as in Run XI.

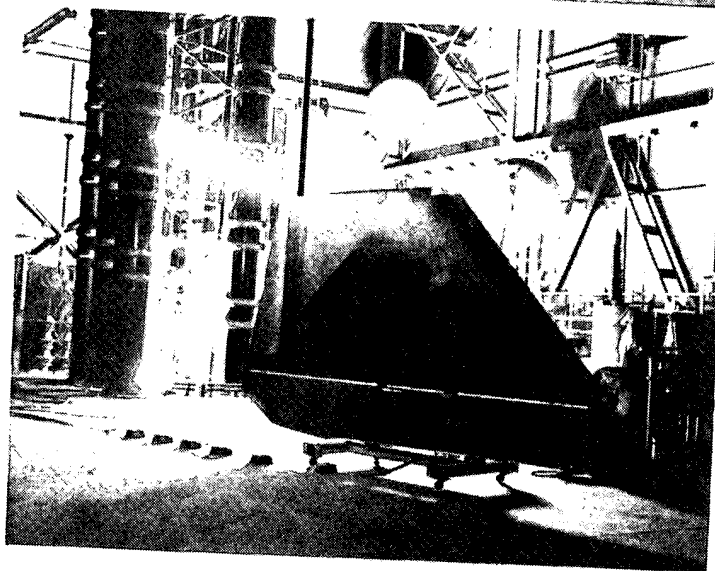


Photo XIII-2.

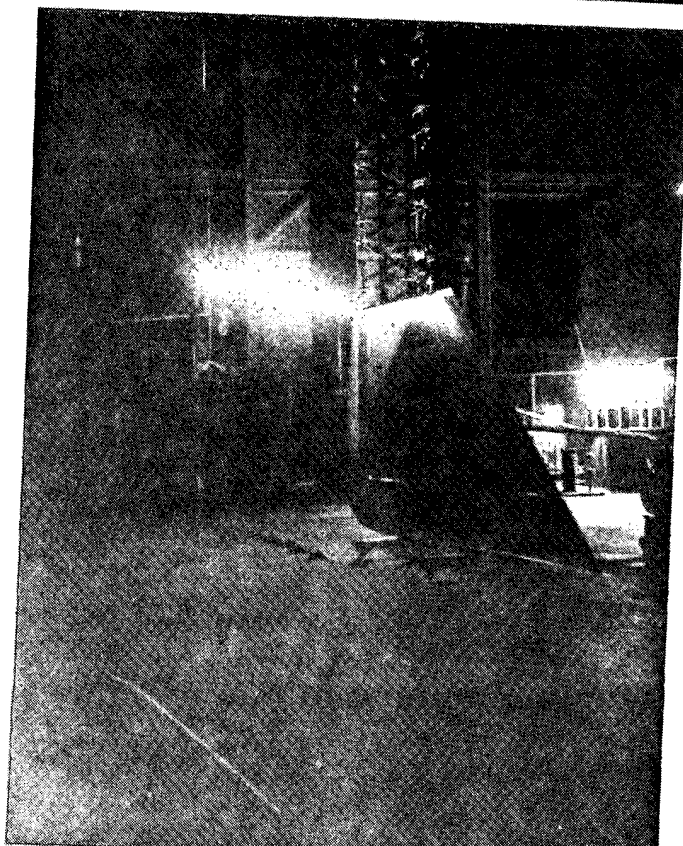


Photo XIII-3.



Photo XIV-1. Run XIV.  
Copper dipoles  
installed.

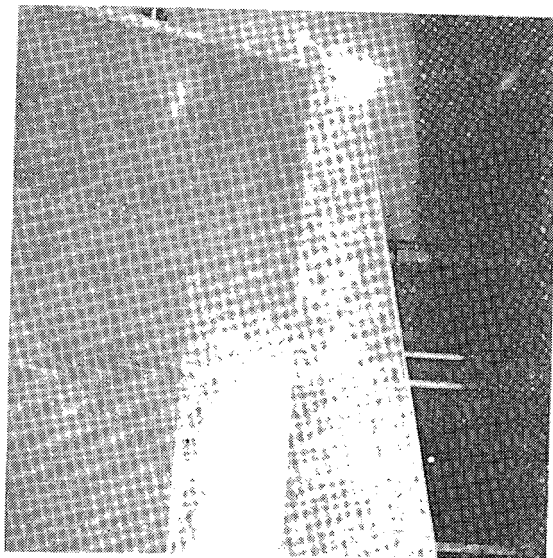


Photo XIV-2. Run XIV.  
Compare with Run XIII  
pictures.  
Aft side discharge.

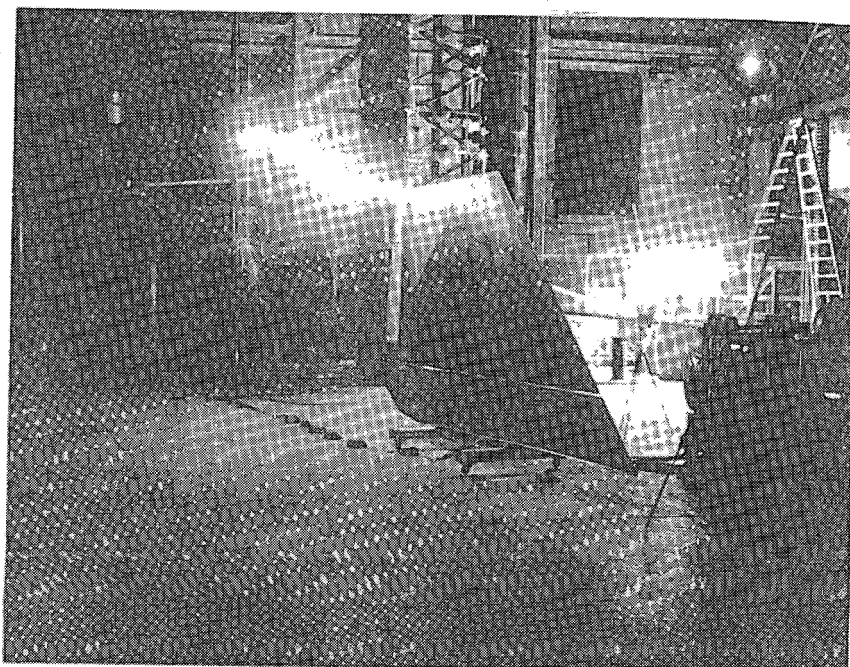


Photo XIV-3.

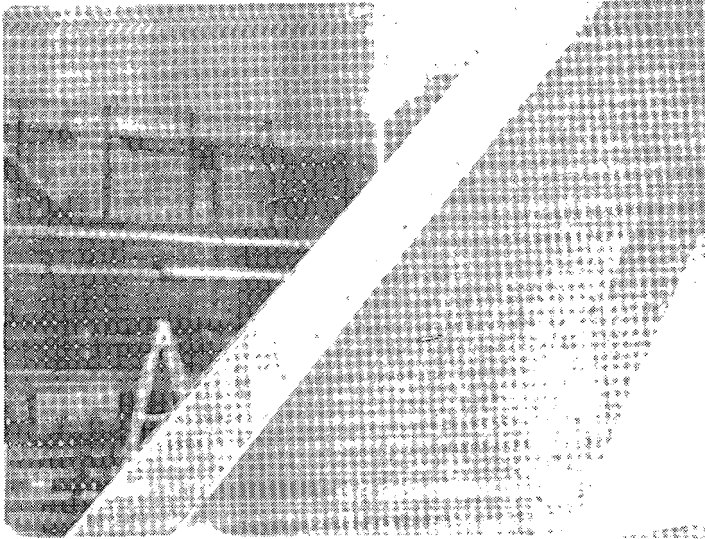


Photo XV-1. Run XV.  
Copper dipoles  
installed.

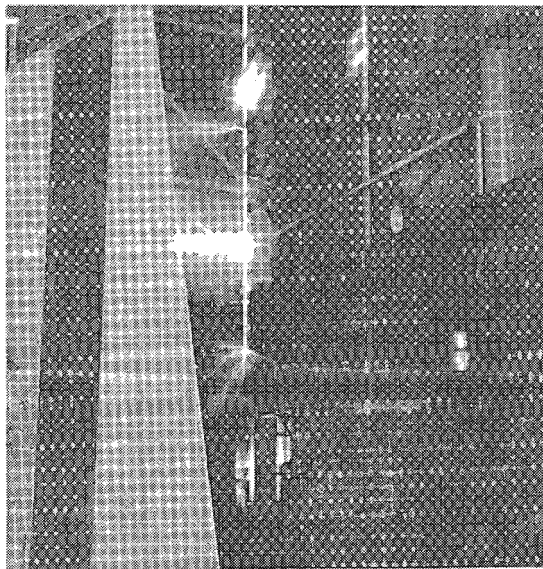


Photo XV-2. Run XV.  
Forward side discharge.



Photo XV-3. Run XV.  
Compare with Photos  
XII-1, -2, and -3 of  
Run XII.

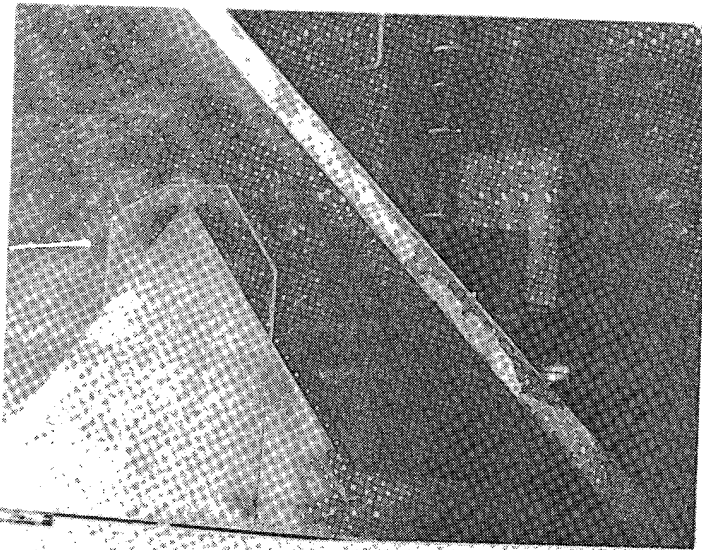


Photo XVI-1. Run XVI.  
Slight indication  
of arcing between  
needles.

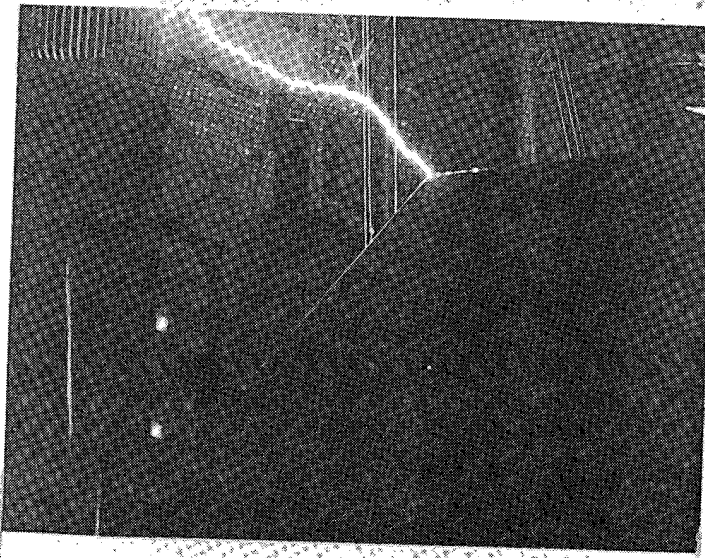


Photo XVI-2. Notice  
bright spots at ends  
of needles along  
leading edge.

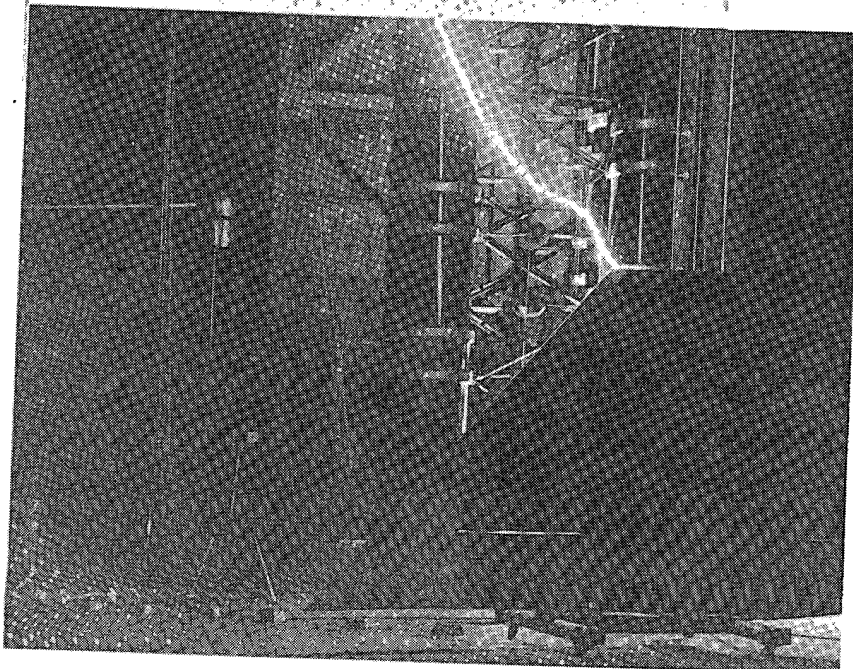


Photo XVI-3. Run XVI.  
Note arc path.



Photo XVII-1. Run XVI  
is a rerun of XVI.

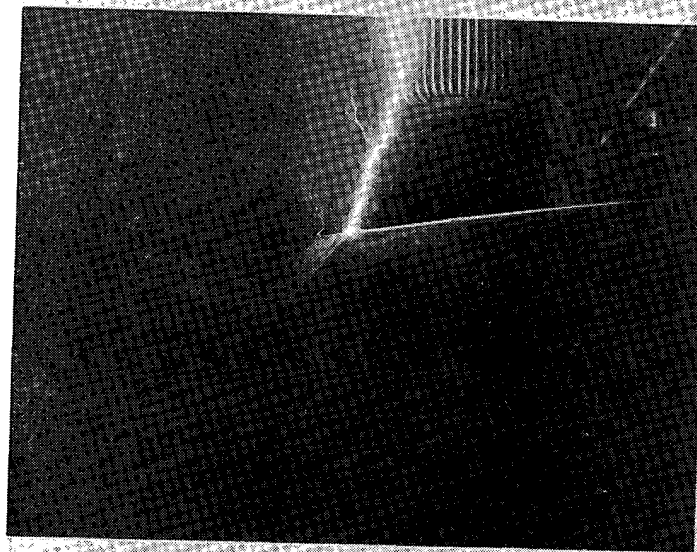


Photo XVII-2.



Photo XVII-3.

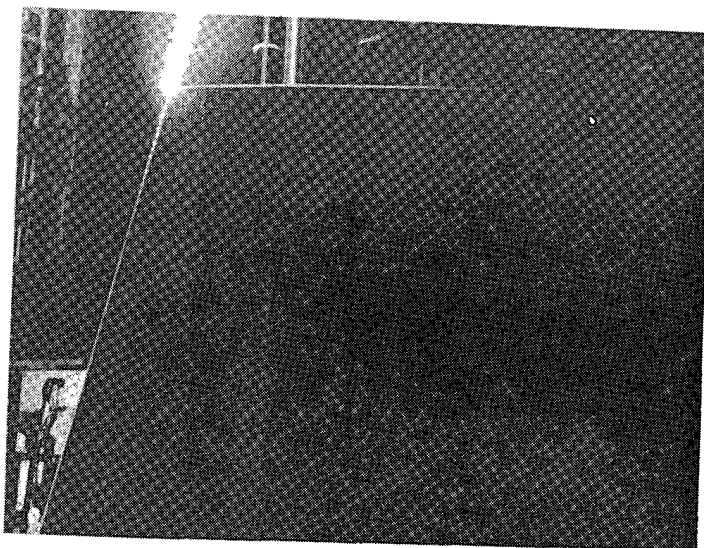


Photo XVIII-1. Run XVIII. Arcing at Ends of Needles is Noticeable along T.E.

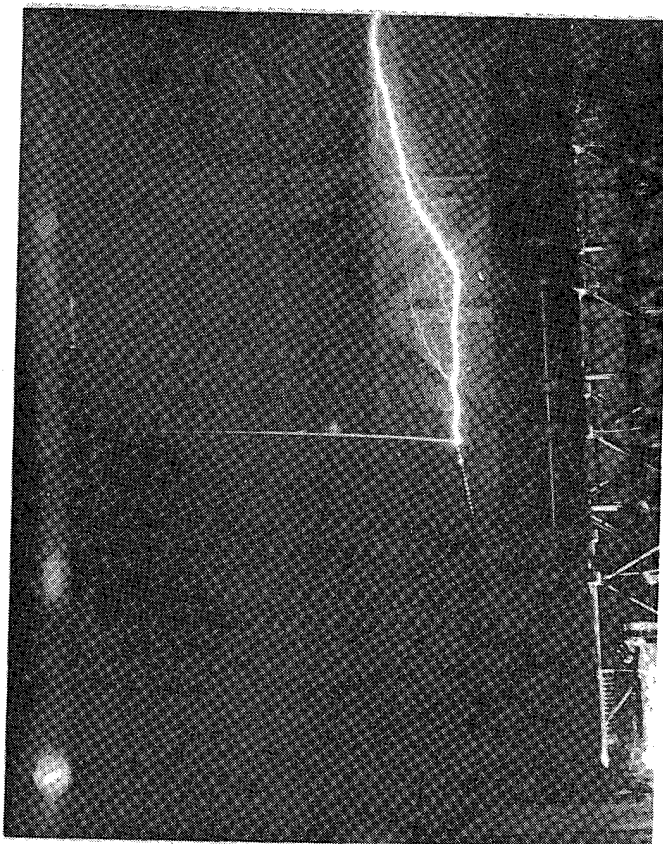


Photo XVIII-2. L.H. Side of T.E. of Rudder.

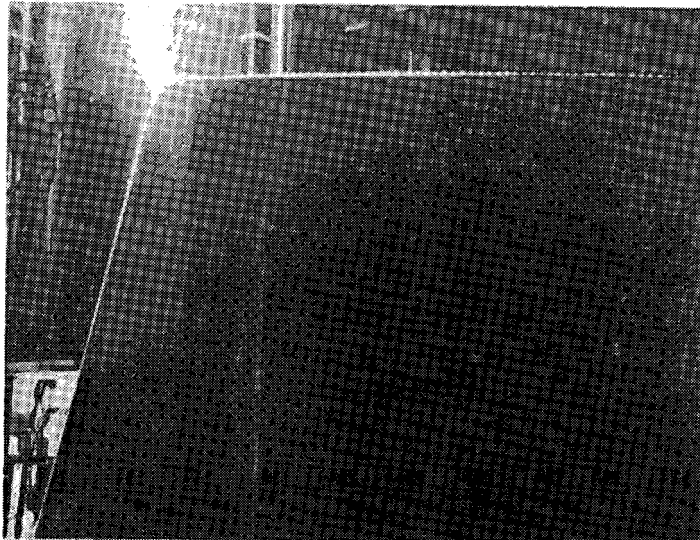


Photo XIX A-1 Run XIXA.  
Definite arcing at ends  
of needles.

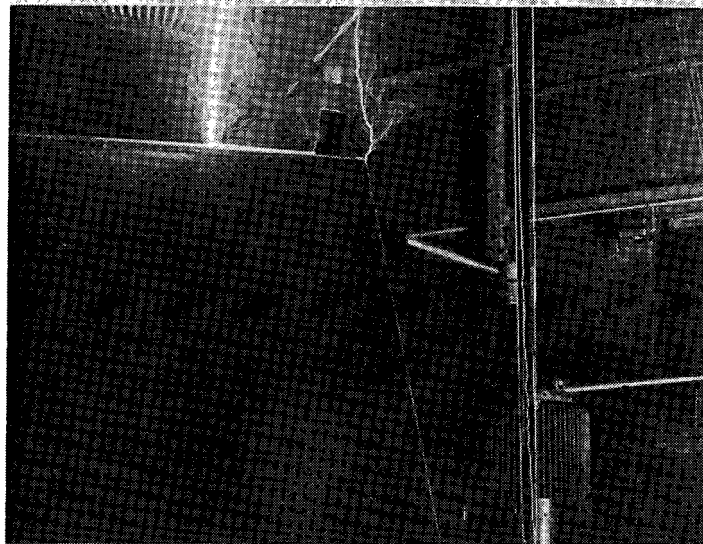


Photo XIX B-1 Run XIXB.  
Compare with Photo XIX A-1.  
Some dipoles were missing  
in this run.

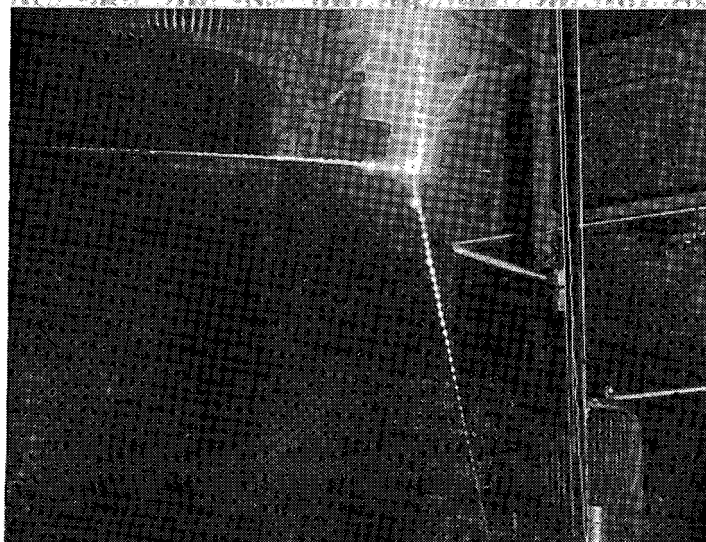


Photo XIX C-1. Run XIXC.  
Missing dipoles replaced.  
Compare with above pictures.

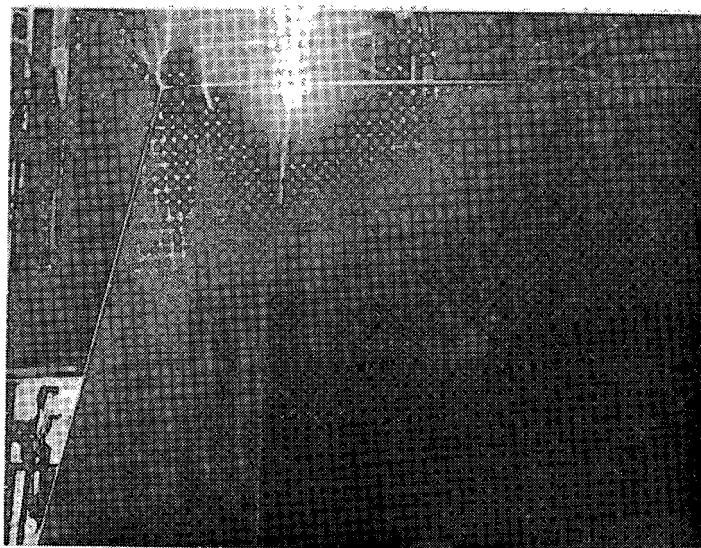


Photo XIX B-2. Run XIX B with missing dipoles.

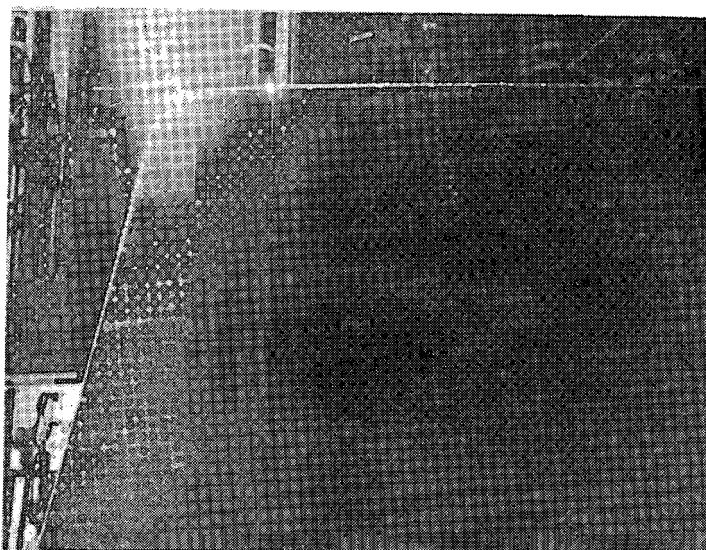


Photo XIX C-2. Run XIX C with dipoles in place.

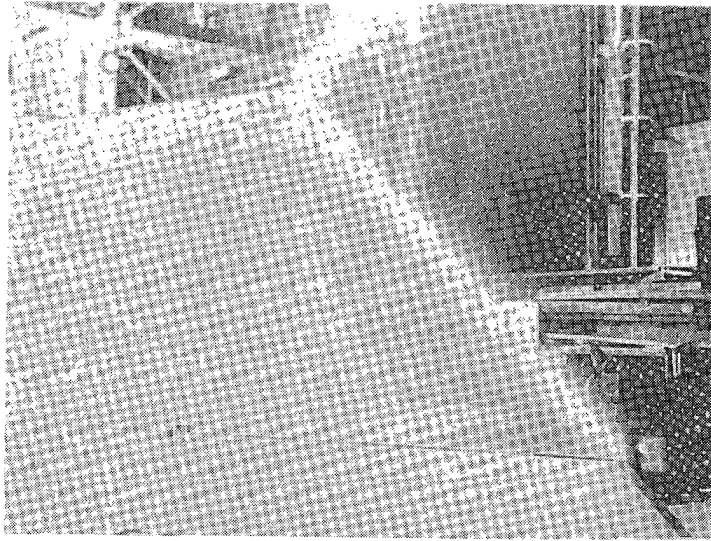


Photo XX-1. Run XX.

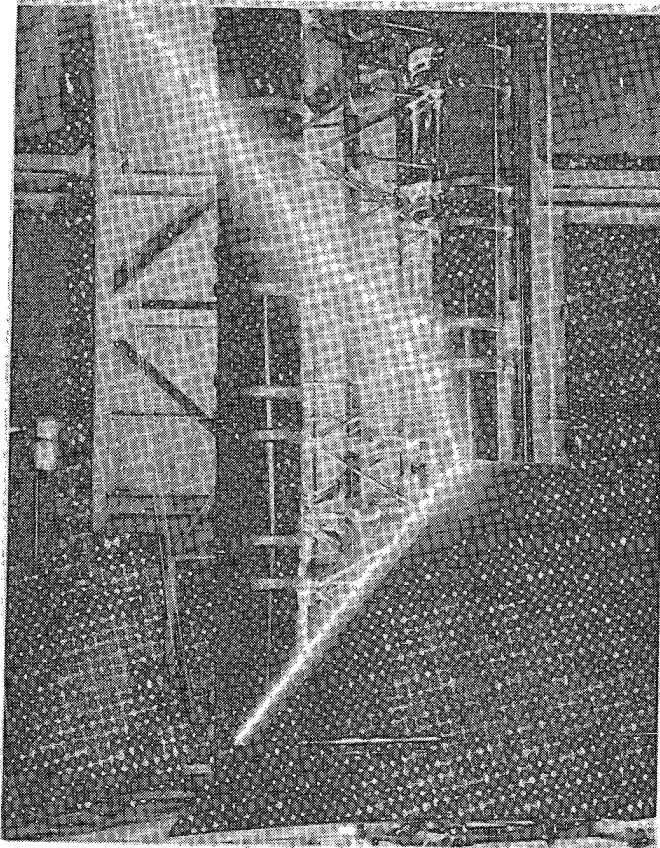


Photo XX-2. Run XX. Compare with earlier shots without dipoles.

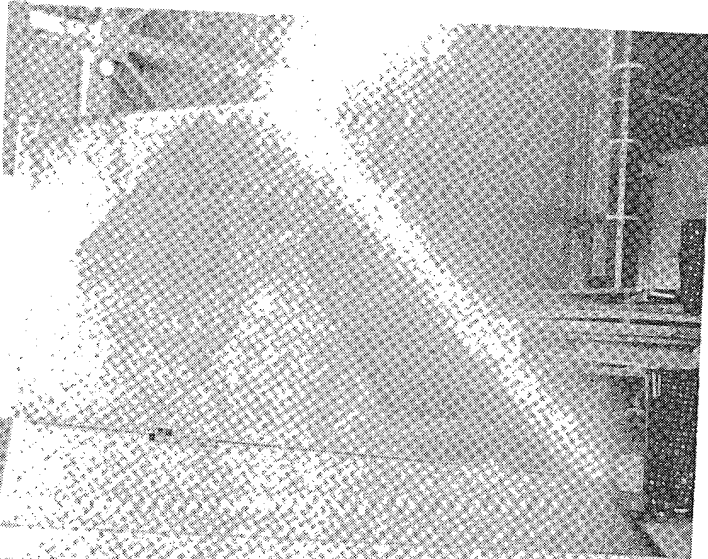


Photo XXI-1. Run XXI.  
Increase in current from  
500 to about 3100 amps  
does not affect rudder.

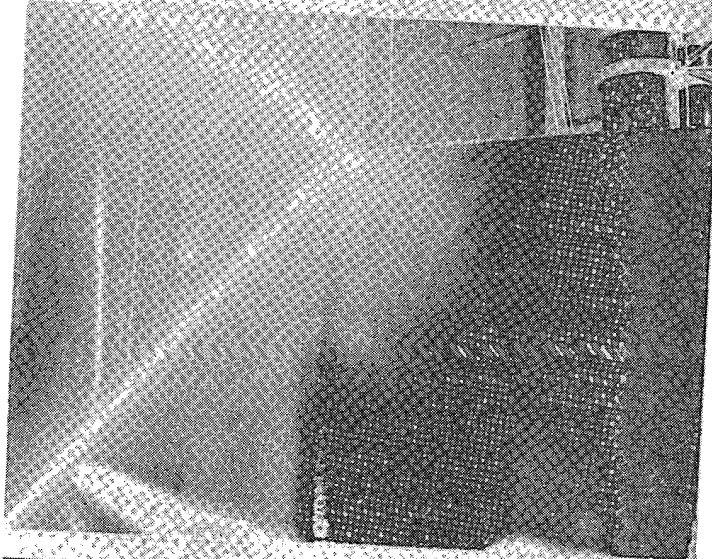


Photo XXI-2.

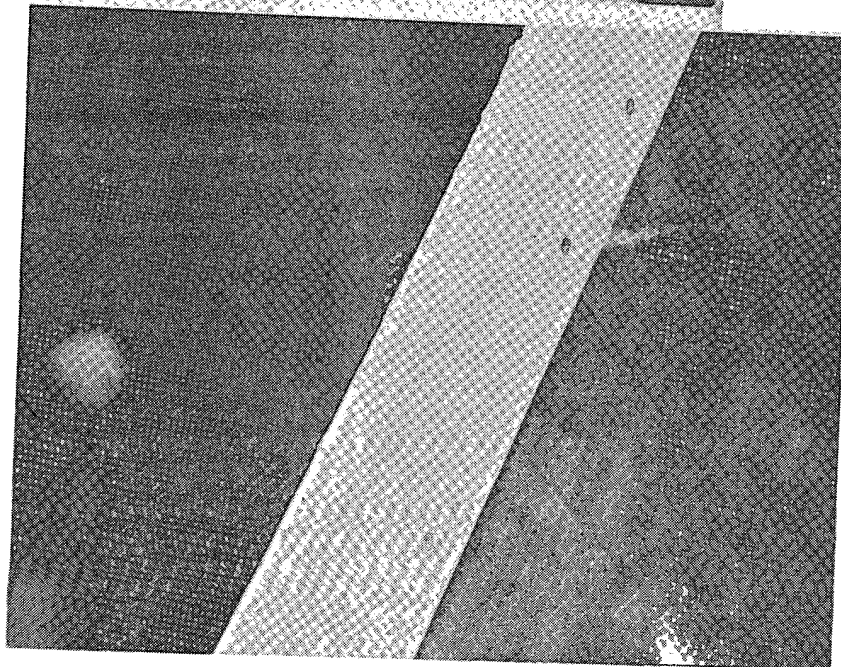


Photo XXI-3. After  
Run XXI. Note burned  
area of leading edge  
in gaps between dipoles.

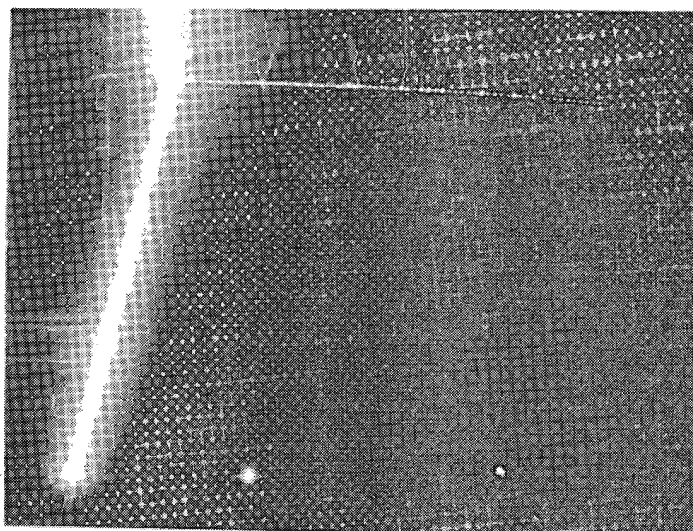


Photo XXII-1.  
Run XXII. Higher  
amperage (approx.  
3100) with strike  
on rear of rudder.

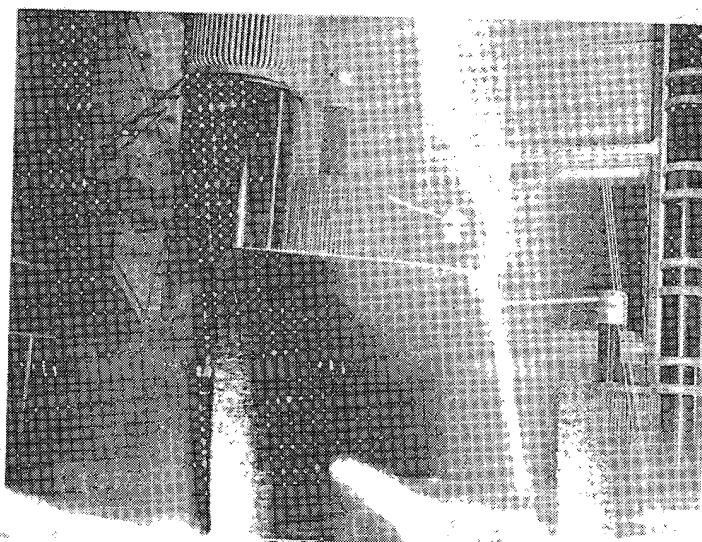


Photo XXII-2.

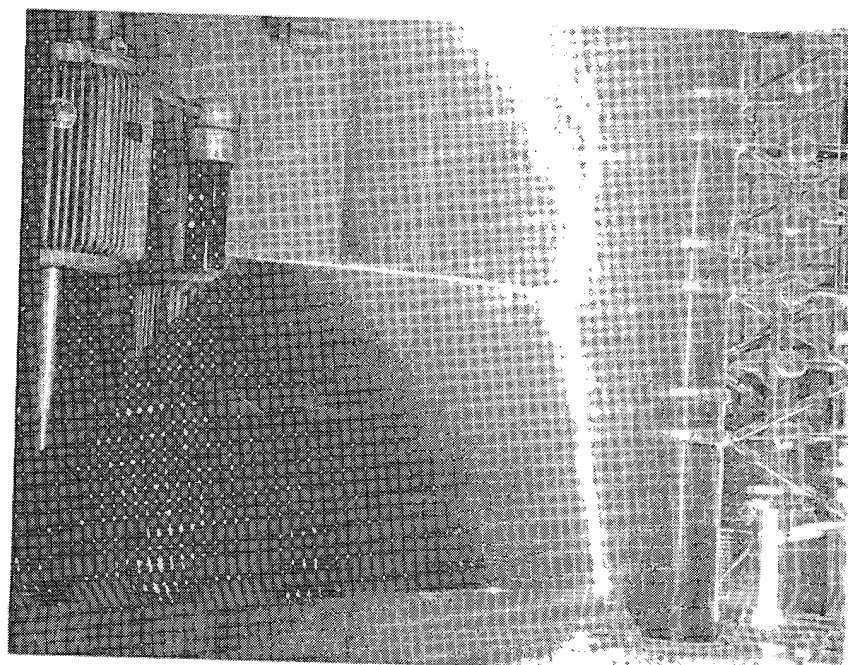


Photo XXII-3.

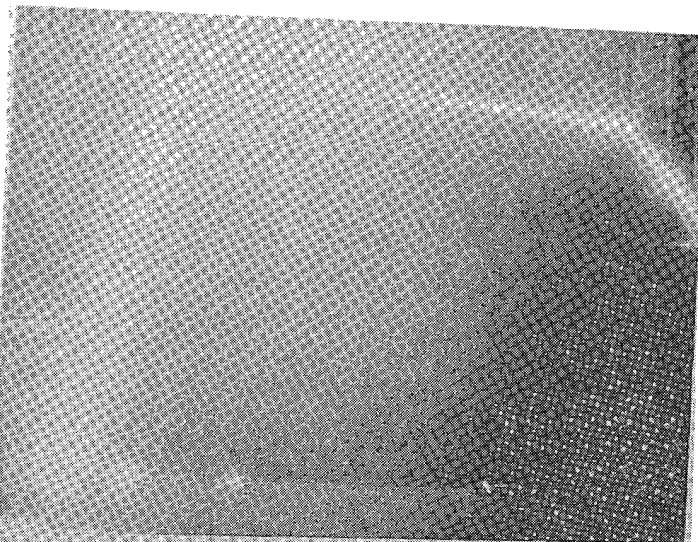


Photo XXIII-1.  
Run XXIII. Higher  
amperage (approx.  
21,800).

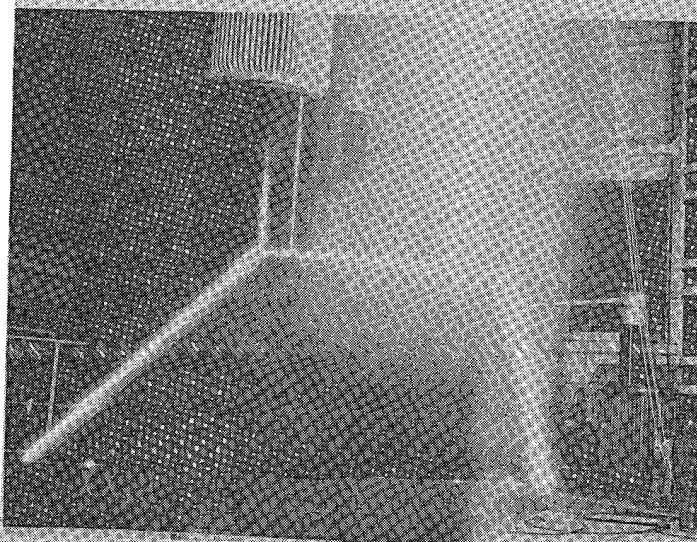


Photo XXIII-2.

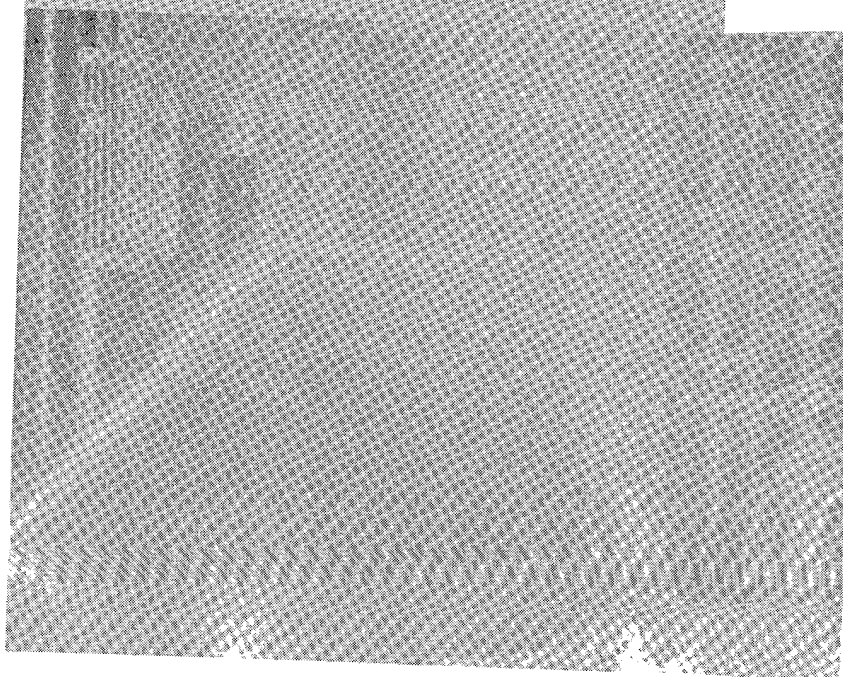


Photo XXIII-3.

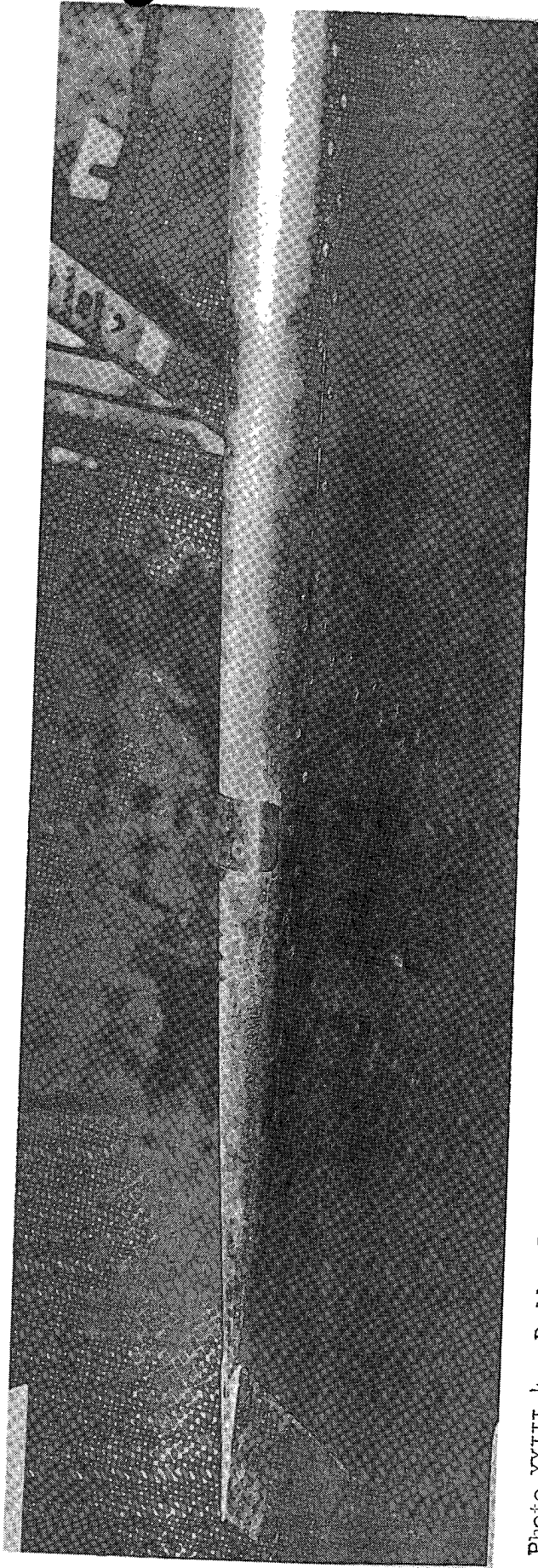


Photo XXIII-4. Rudder L.E. tip with needles removed. Note burned area.

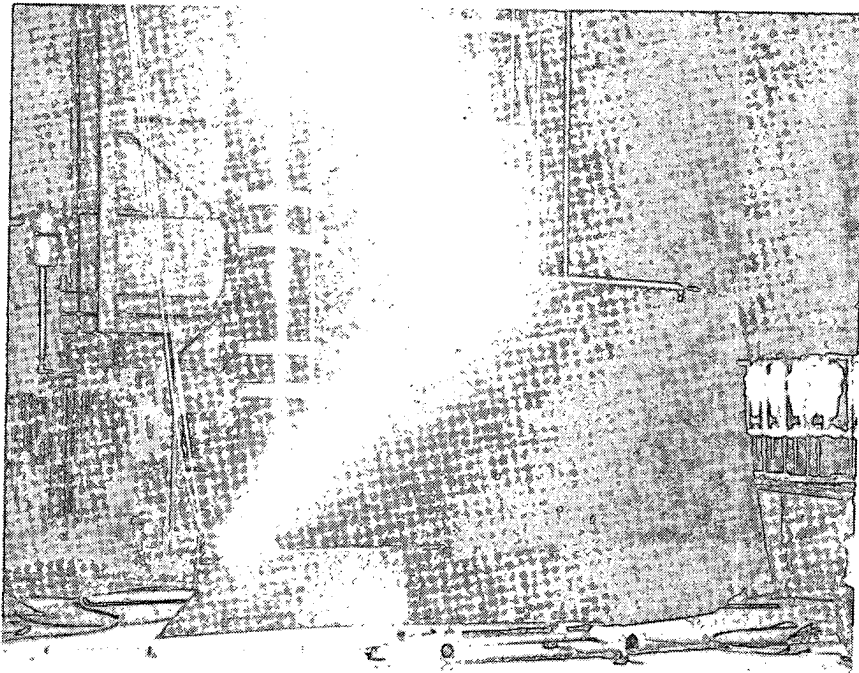


Photo XXIV-1. Run XXIV at 30,800 amps and 4,386,000 volts. Forward strike.

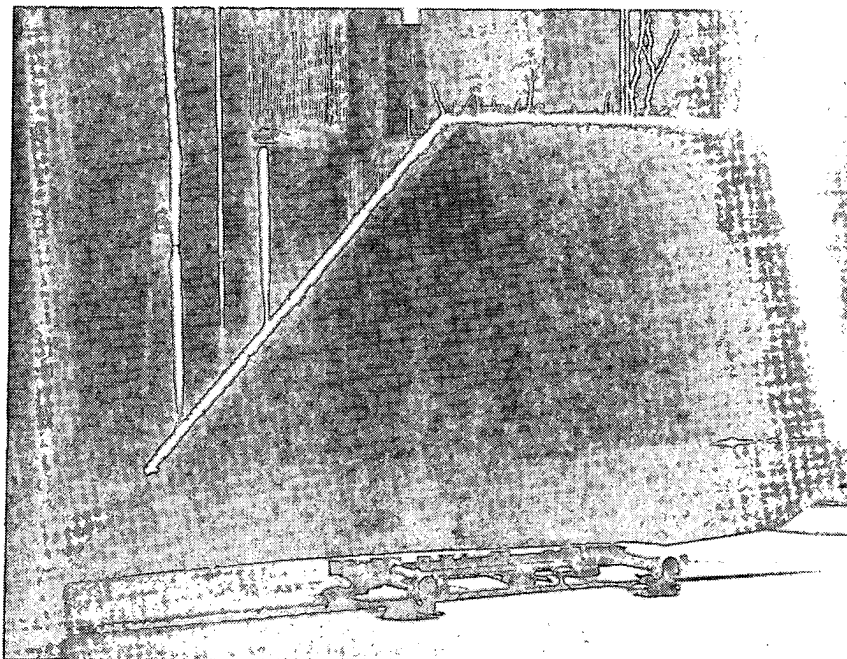


Photo XXV-1. Run XXV. Rear strike of same intensity as previous run.

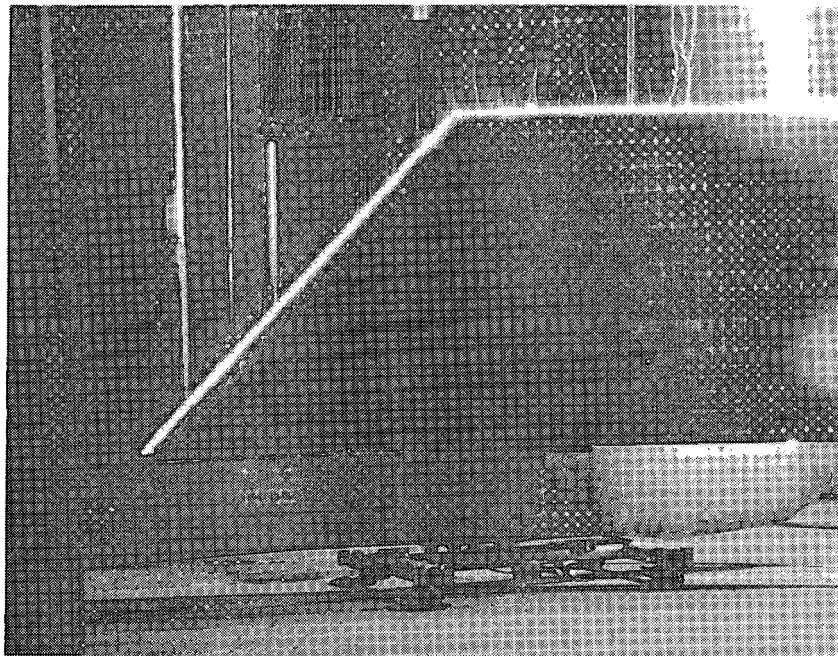


Photo XXVI-1. Rudder deflected for same change as in Run XXV. Path of arc is around rudder.

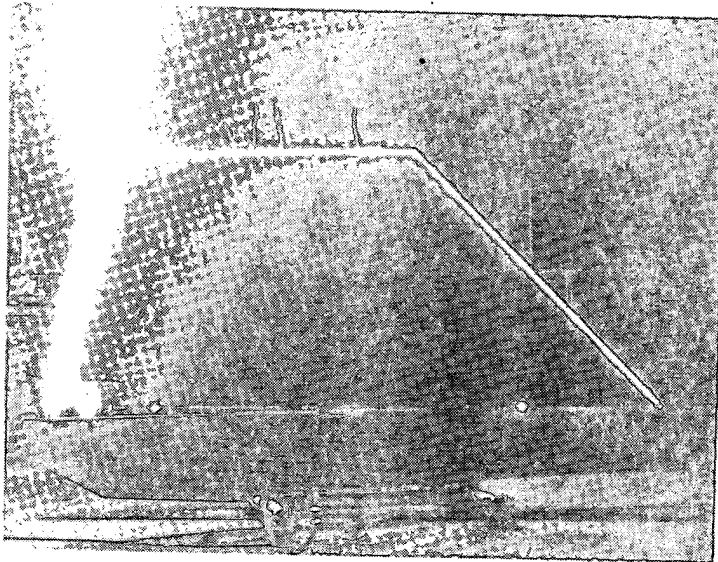


Photo XXVI A-1. Run XXVI A duplicated previous run. Note arcs along bottom closing rib.

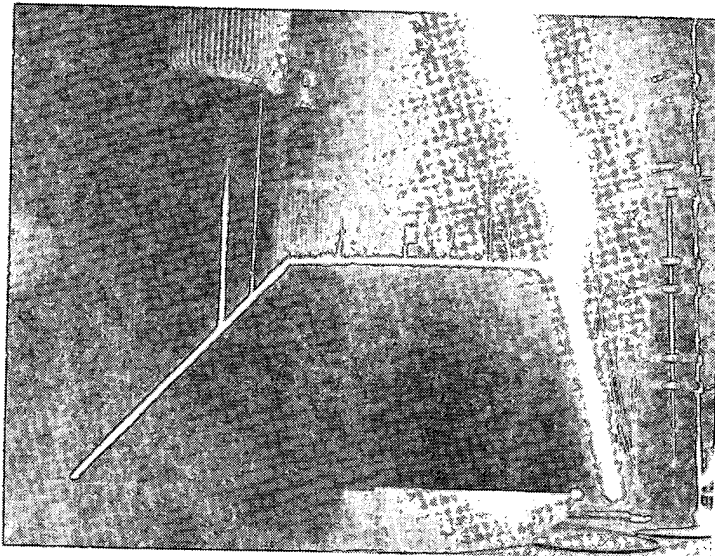


Photo XXVI A-2.

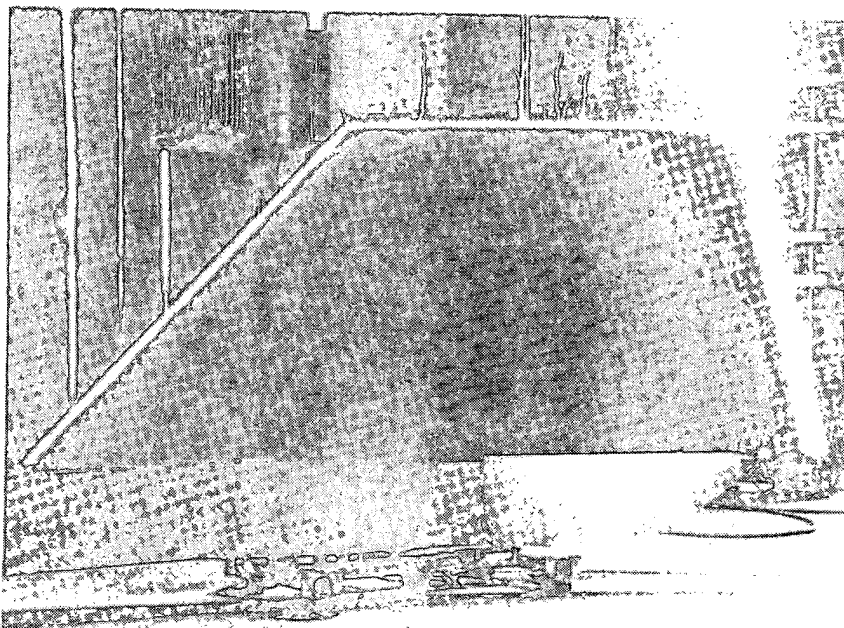


Photo XXVI A3

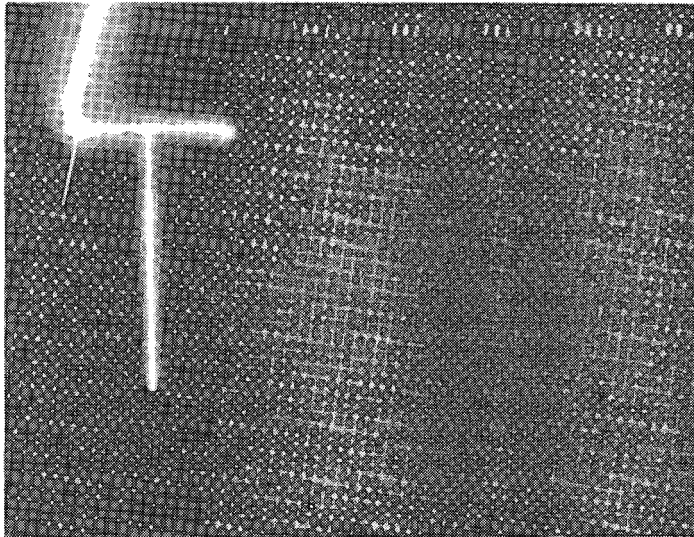


Photo XXVII-1. Run XXVII.  
Aft electrode position.  
Copper dipoles removed  
R.H. side.

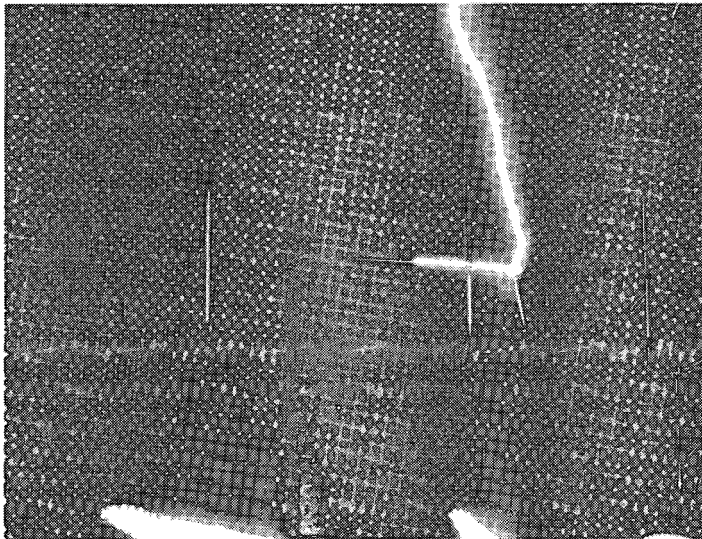


Photo XXVII-2. L.H. side.

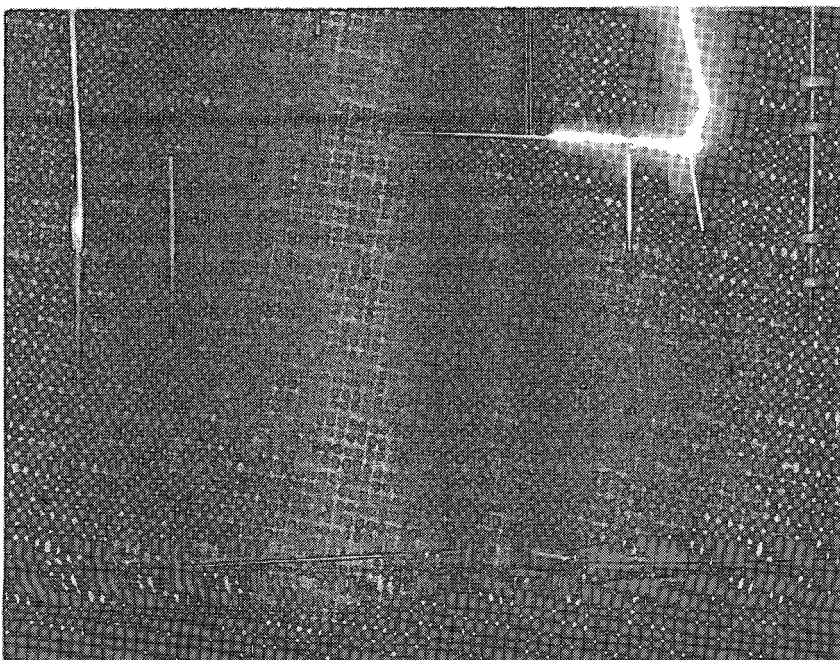


Photo XXVII-3.

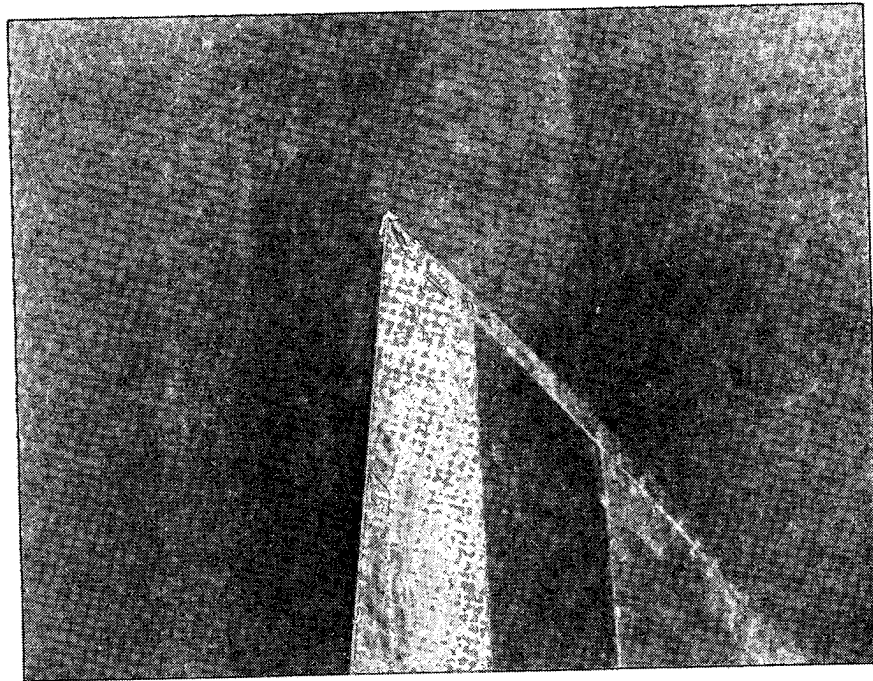


Photo XXVII-4. Rudder tip trailing edge after Run XXVII.

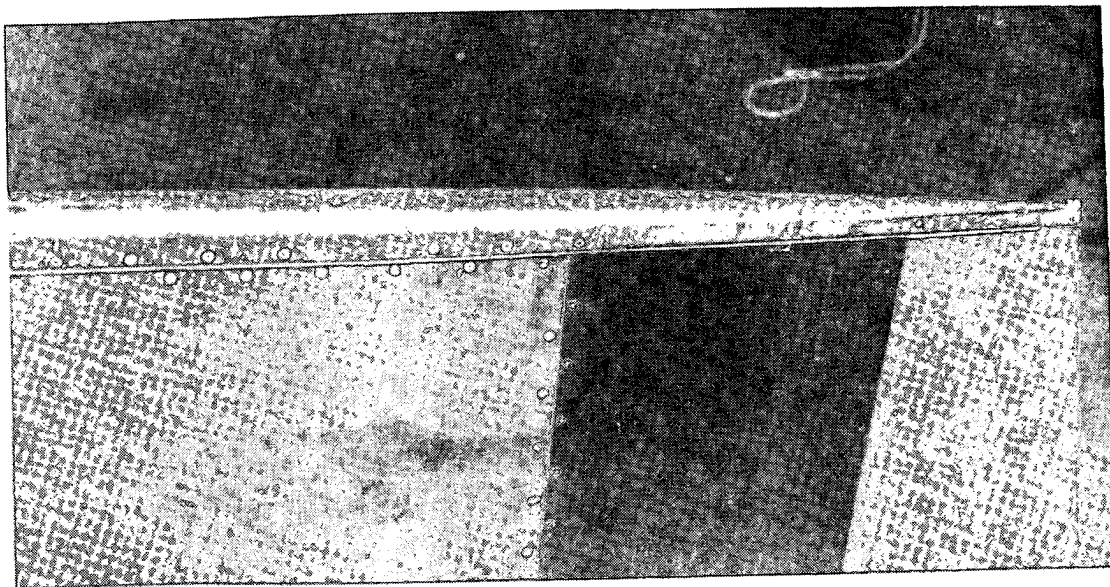


Photo XXVII-5. Rudder tip after Run XXVII. Note tracking. Dark spots are burns from arcs between dipoles used in previous runs.

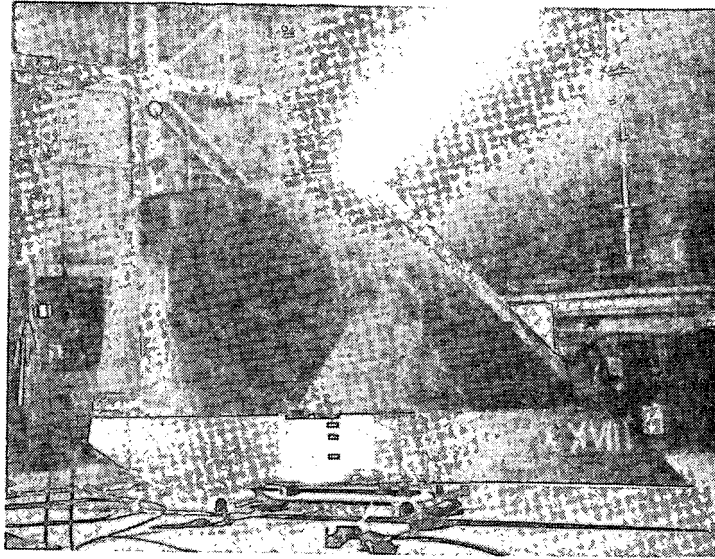


Photo XXVIII-1. Run XXVIII. Forward electrode position. Copper dipoles removed.

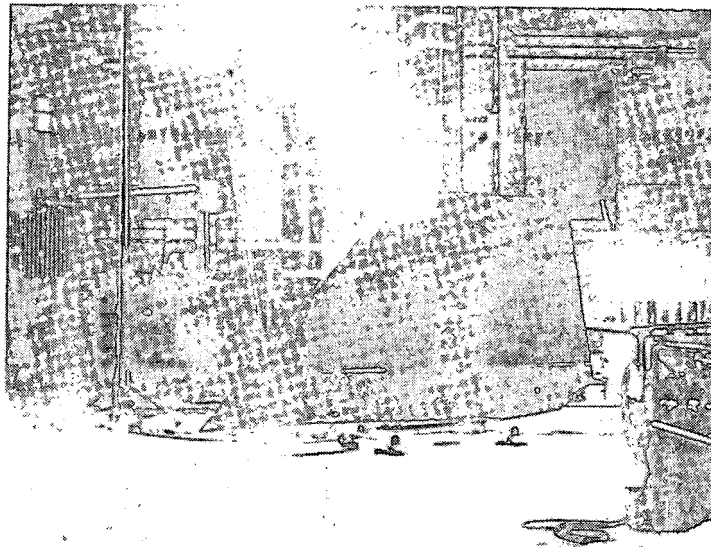


Photo XXVIII-2. Same as above. No visible external damage except for tracking on top.

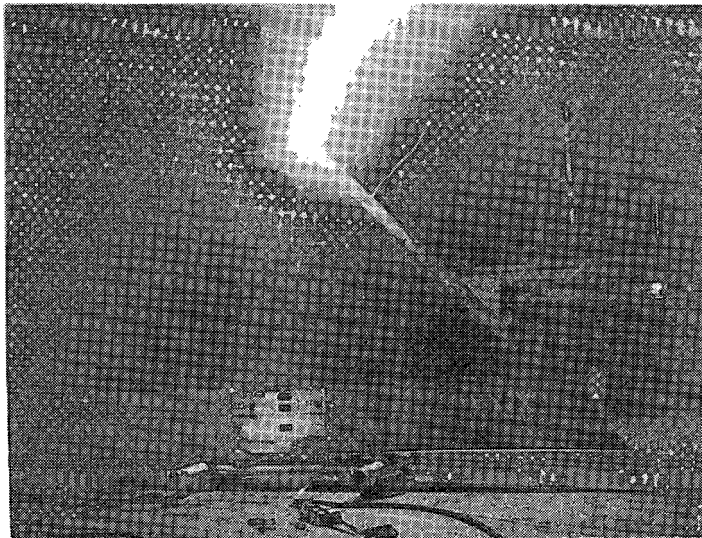


Photo XXIX-1. Run XXIX.  
R.H. side. Dipoles  
removed.

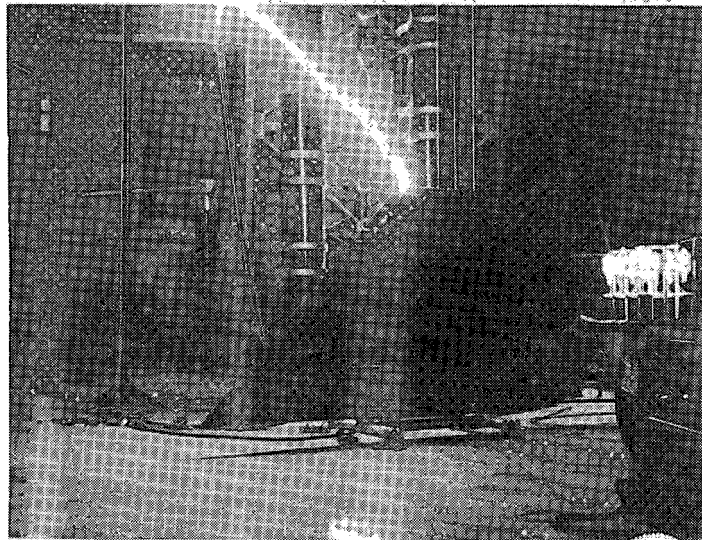


Photo XXIX-2. L.H. side  
Note puff of smoke along  
L.E. which located  
negligible damage area.

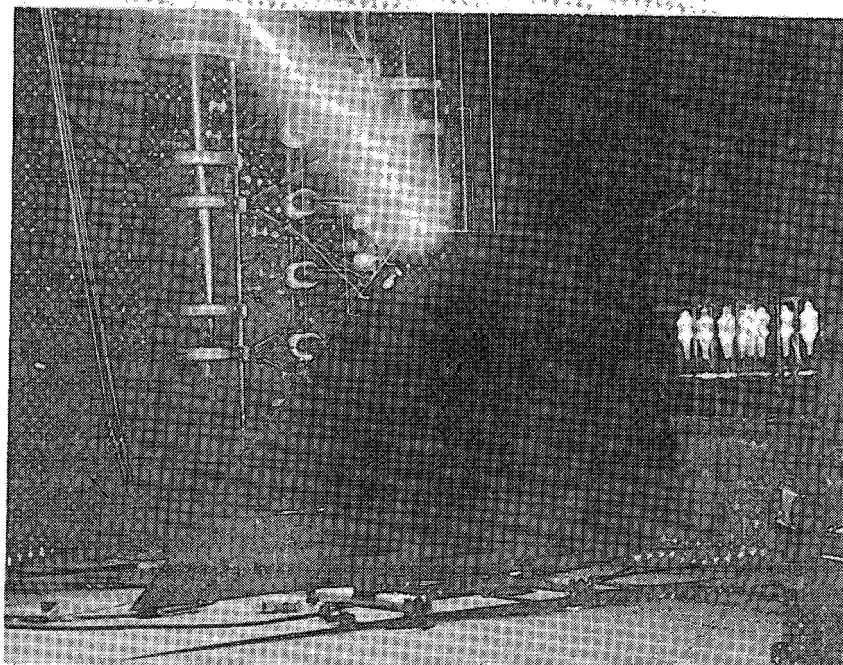


Photo XXIX-3.

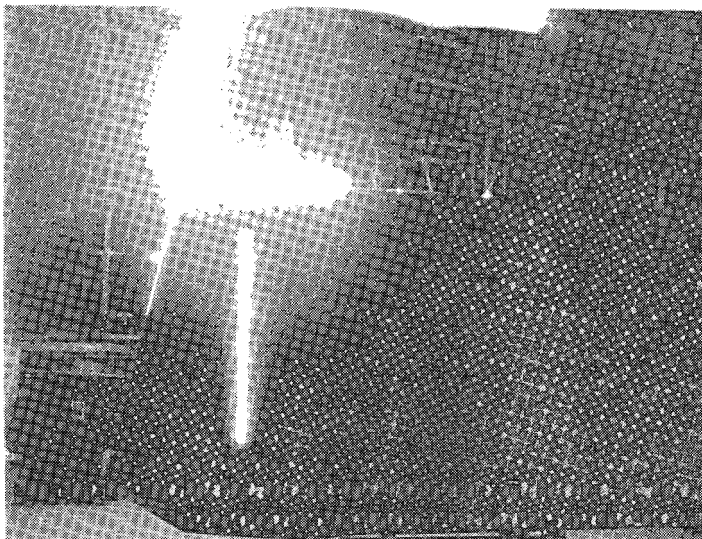


Photo XXX-1. Run XXX.  
T.E. strike with no  
"needles". Not part  
of arc along top and  
sudden termination.  
See Photos XXX-4 and 5.

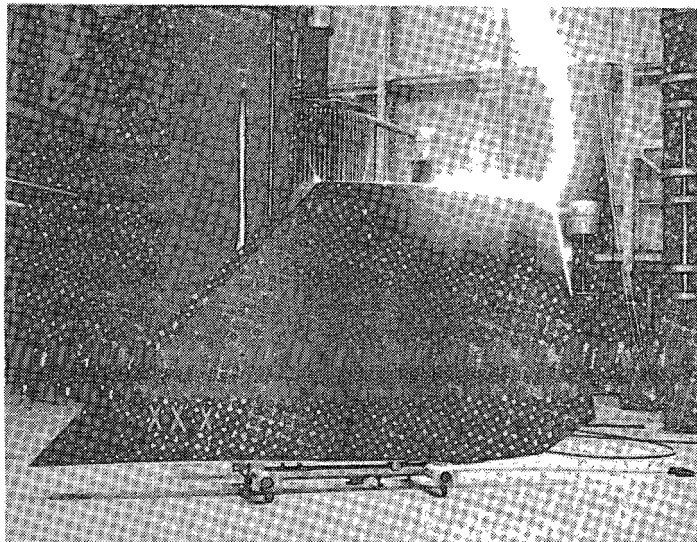


Photo XXX-2. L.H.  
side.

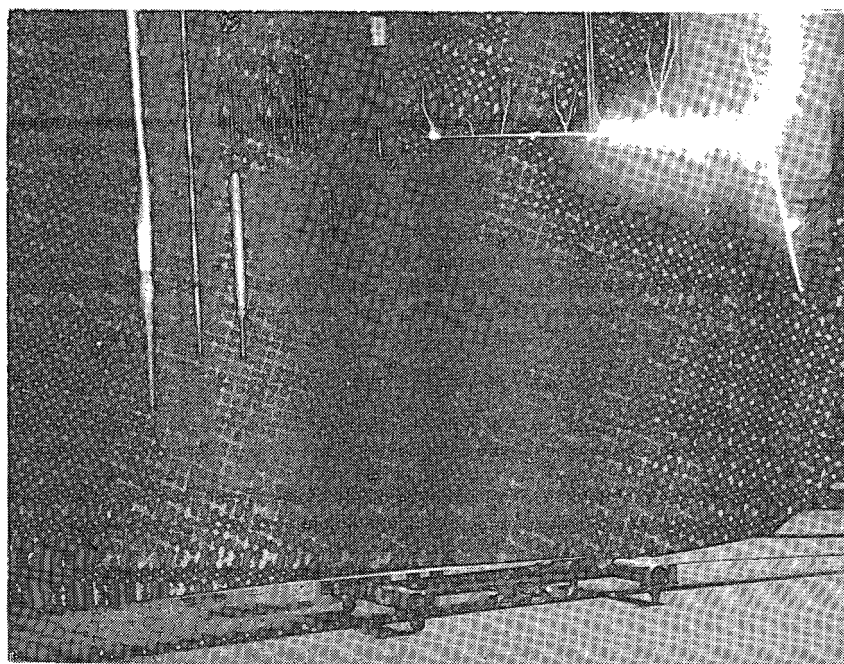


Photo XXX-3.

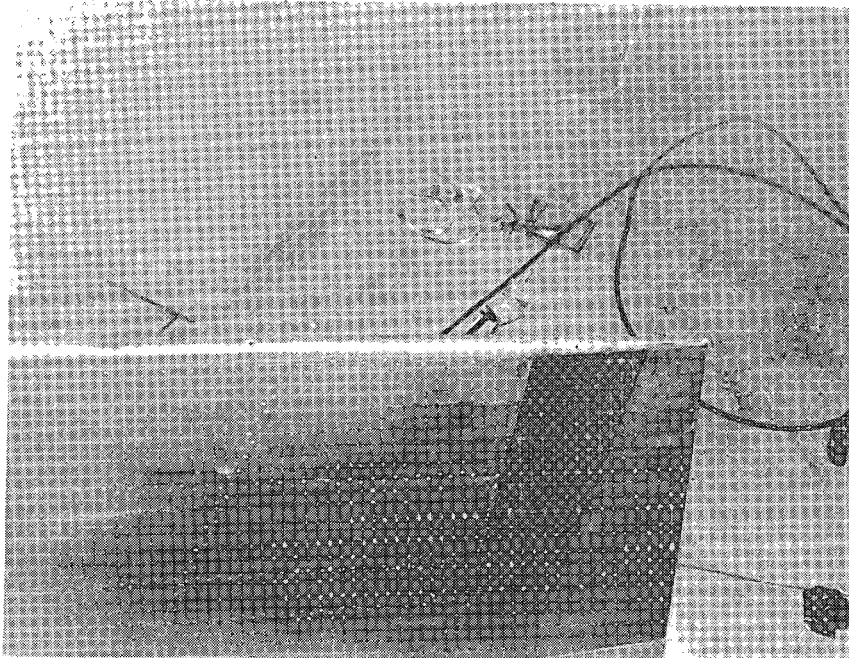


Photo XXX-4. Rudder tip after run No. XXX.

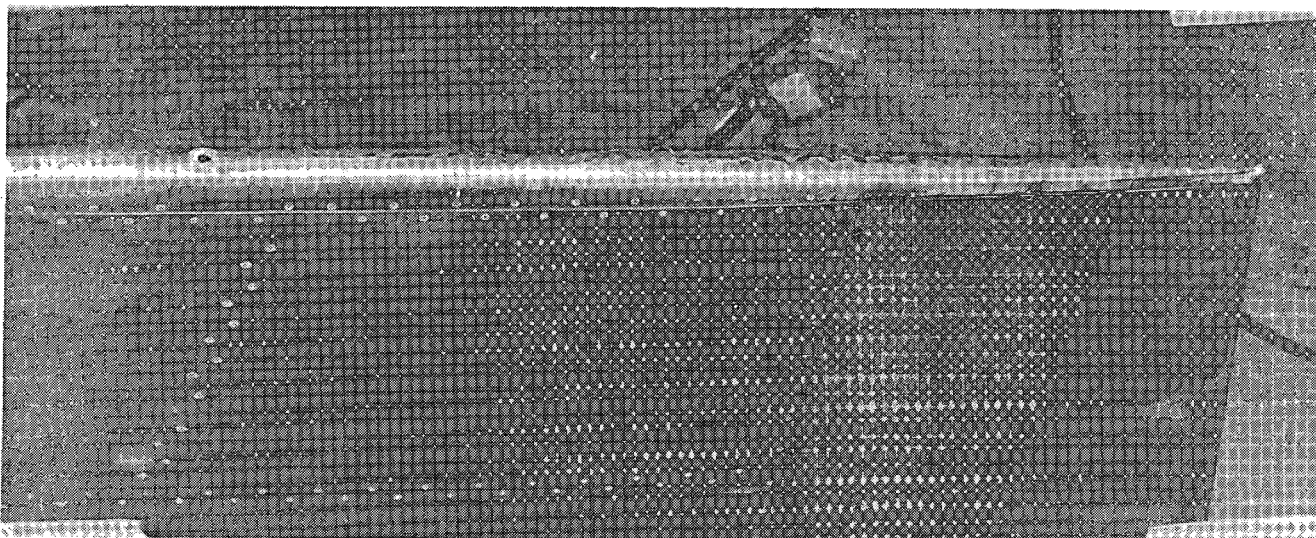


Photo XXX-5. Rudder tip - Note tracking and blown out patch.

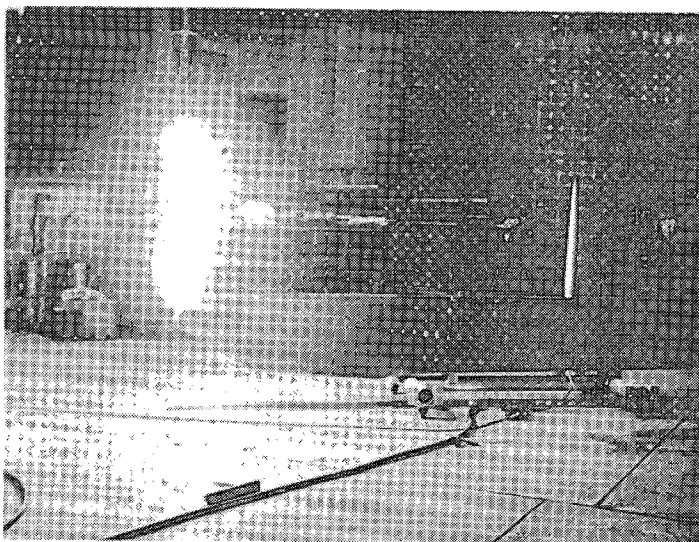


Photo XXXI-1. Run XXXI.  
Stub fin shot to T.E.

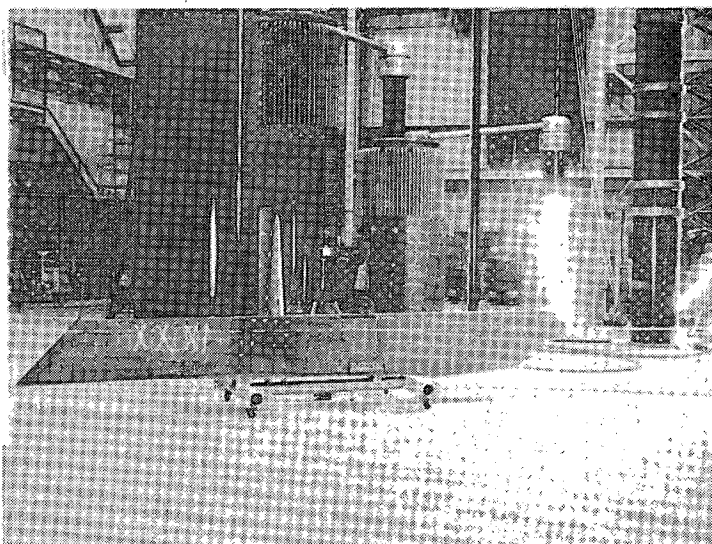


Photo XXXI-2.

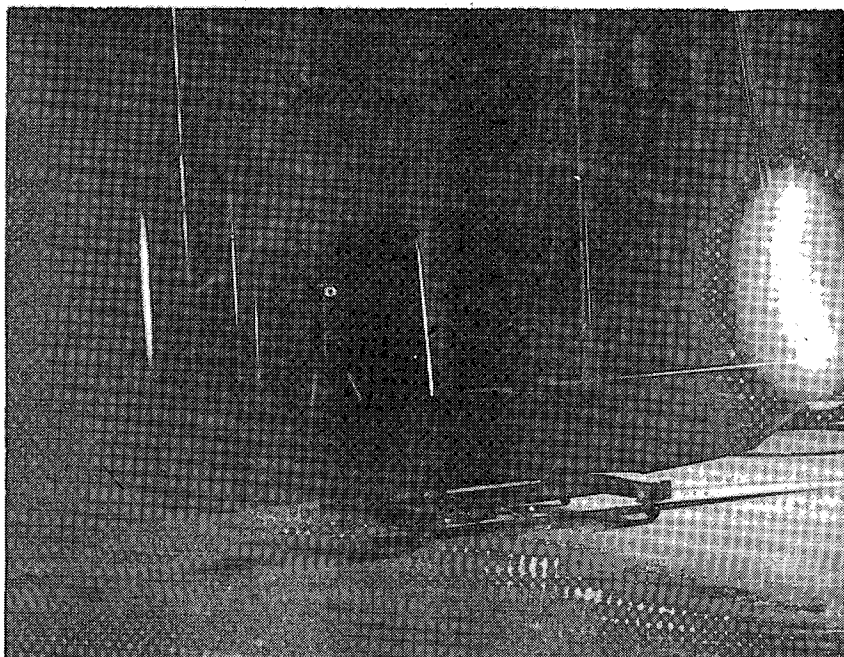


Photo XXXI-3.

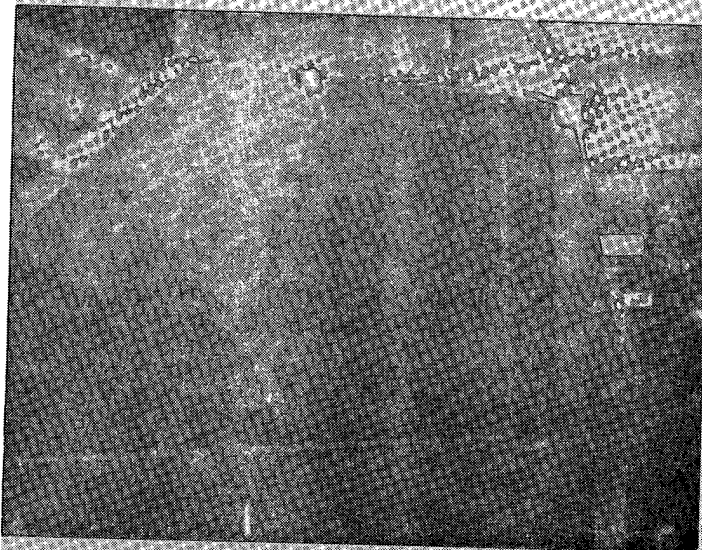


Photo 1-1. Run 1.  
Note emergence of  
arc at about 30 percent  
chord point on tip.  
Slight damage.



Photo 1-2.

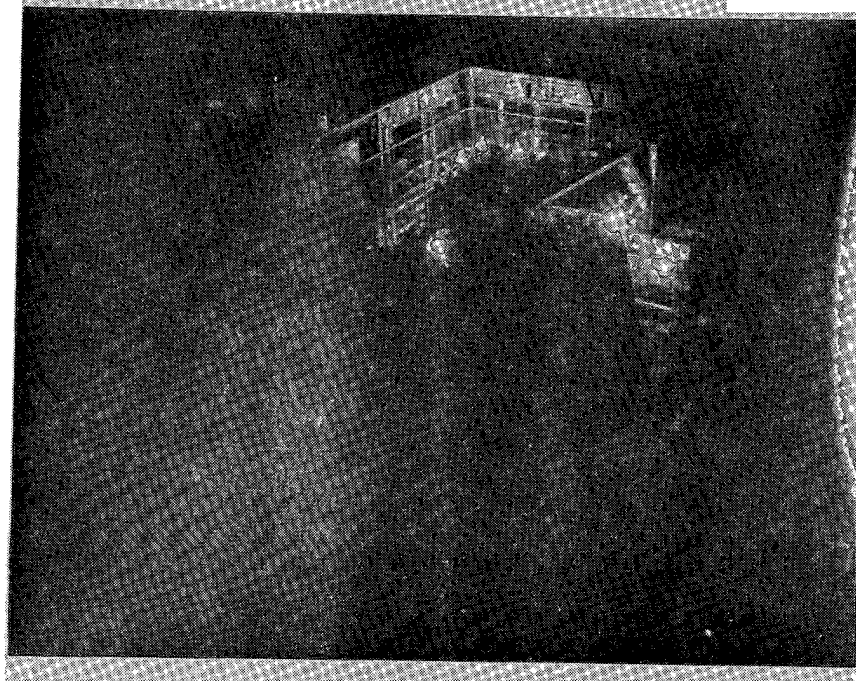


Photo 1-3.



Photo 2-1. Run 2. R.H. side of rudder.  
Note incandescent foil particles.



Photo 2-2. L.H. side of rudder.

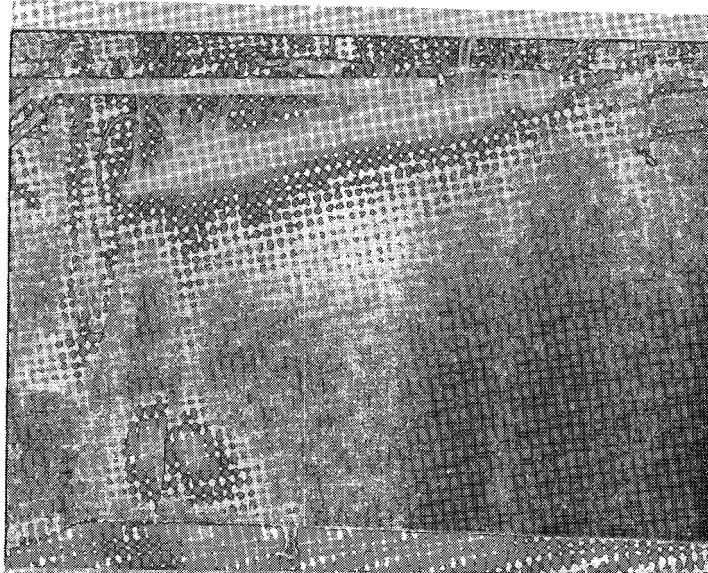


Photo 3-1. Run 3.  
Foil gaps reduced to 1/8  
inch. Compare with Photos  
1-1 through 1-3.

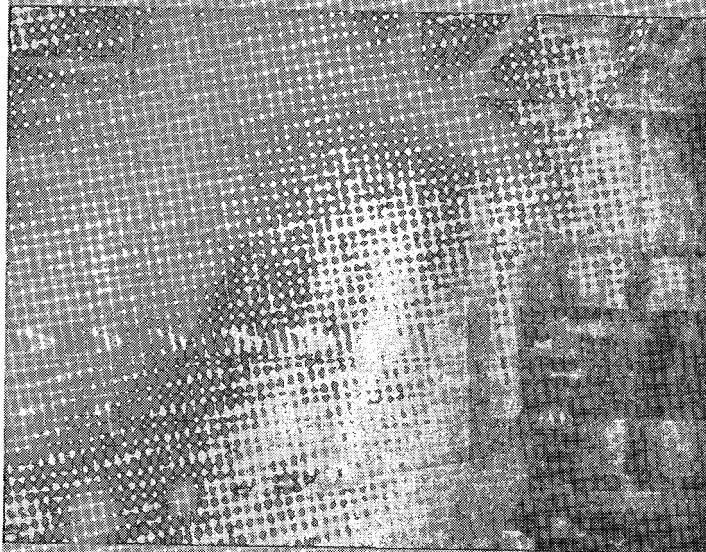


Photo 3-2.



Photo 3-3.



Photo 4-1. Run 4.

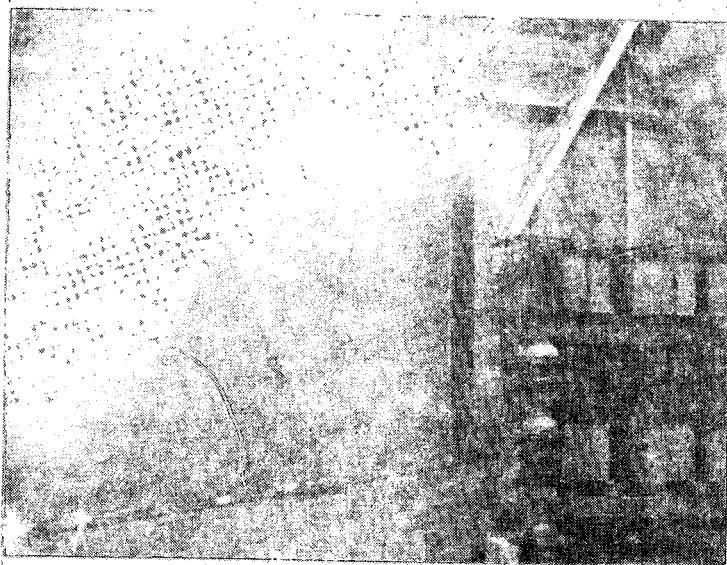


Photo 4-2.

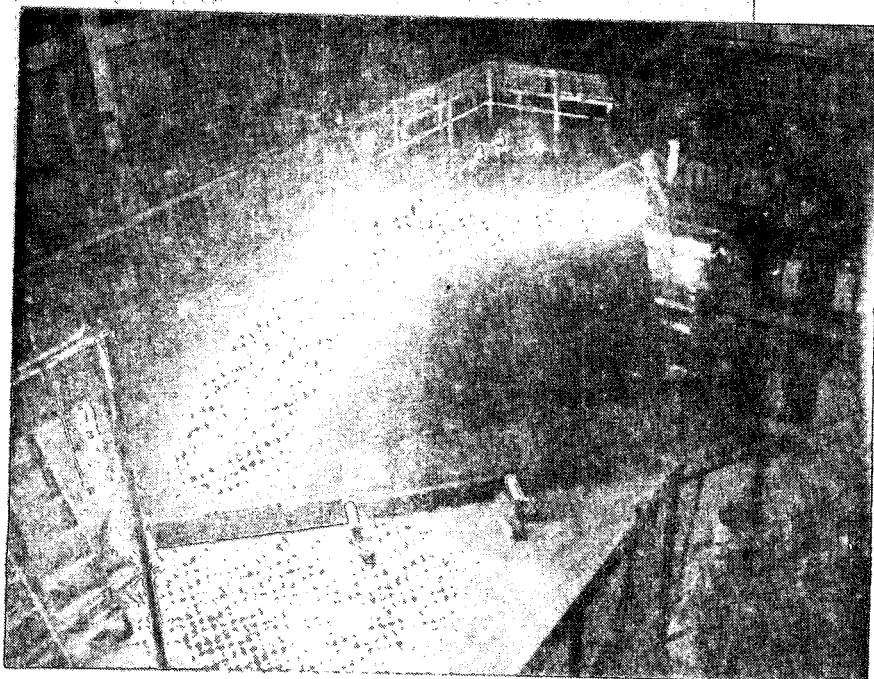


Photo 4-3.

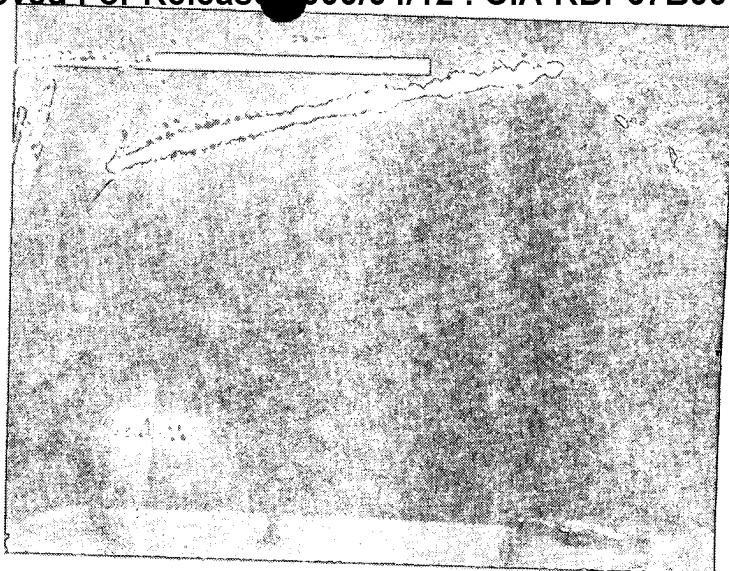


Photo 5-1. Run 5.

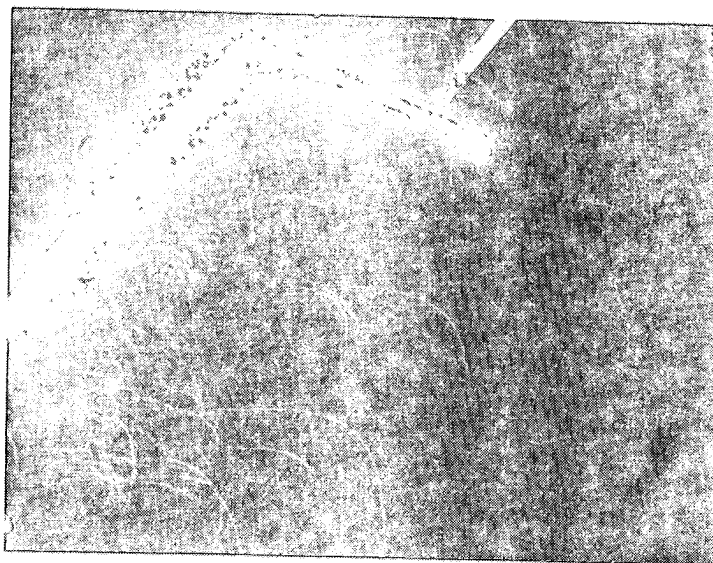


Photo 5-2.

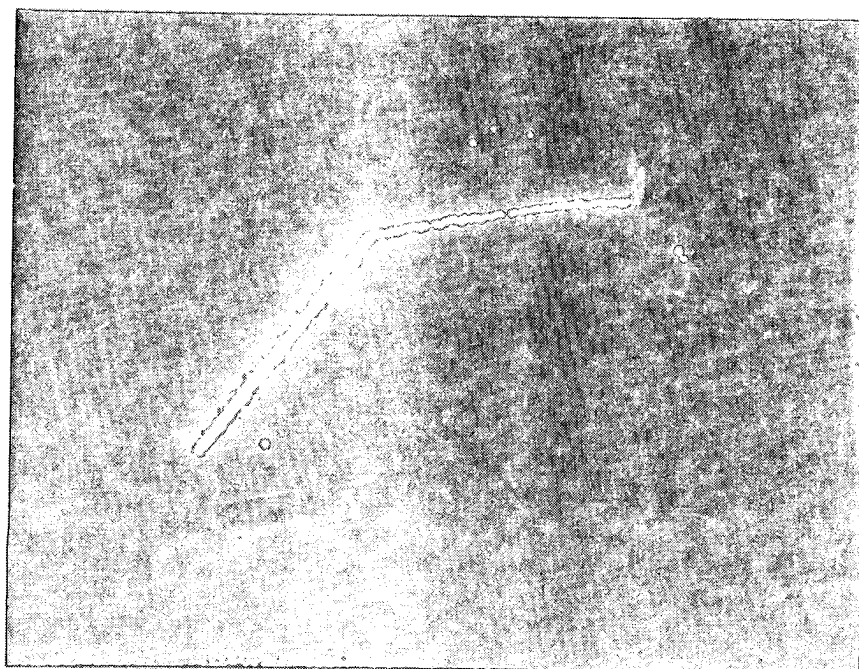


Photo 5-3.

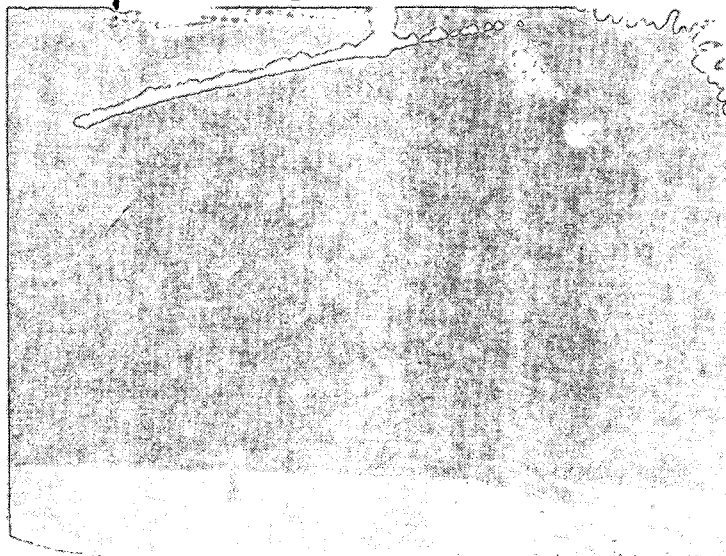


Photo 6A-1. Run 6A.  
Gaps between tapes had  
widened due to arcing.  
Note puff of smoke on  
L.E. where slight damage  
occurred.

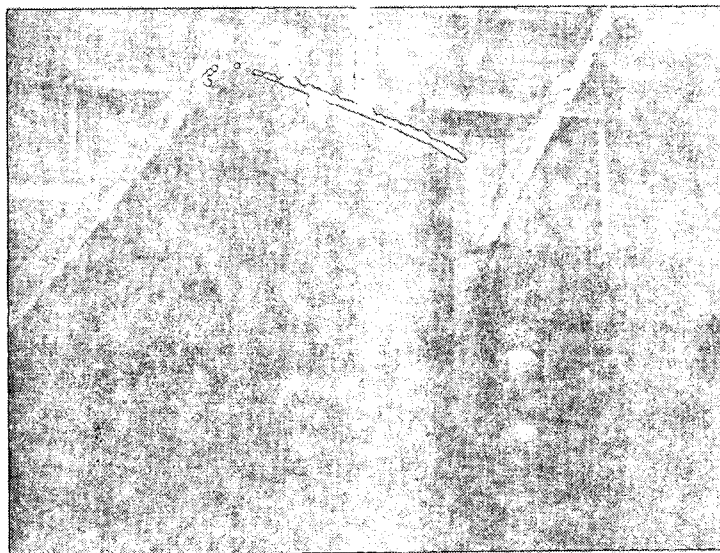


Photo 6A-2.

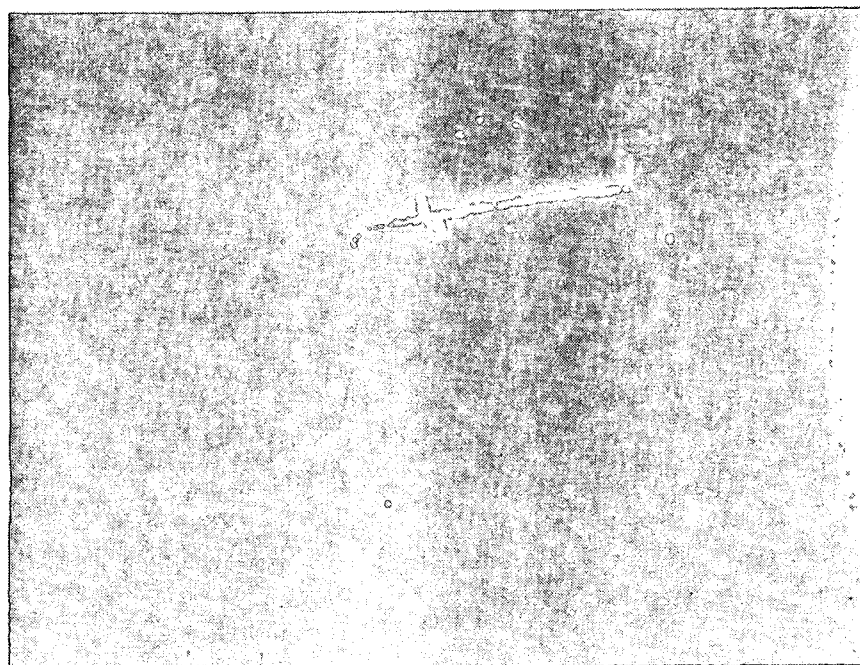


Photo 6A-3.  
Note "puff of smoke"  
area. Slight damage  
found.

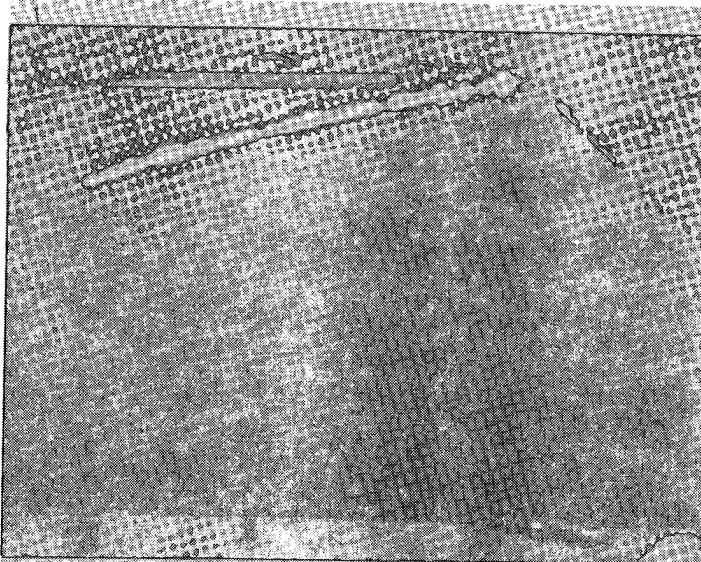


Photo 6-1. Run 6.

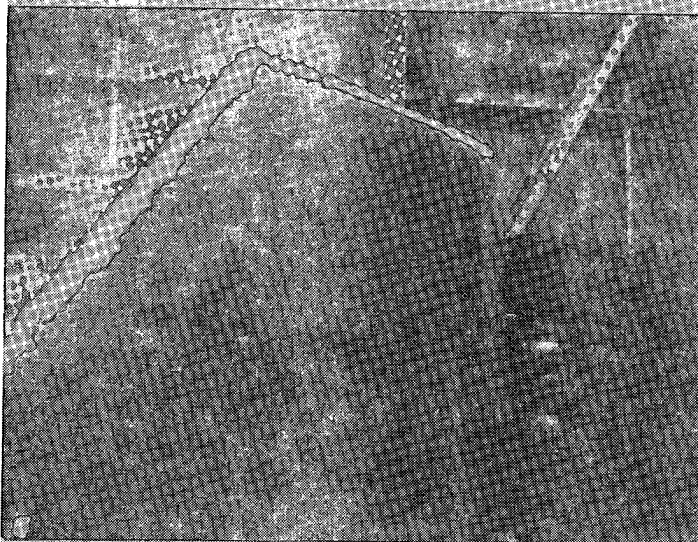


Photo 6-2.

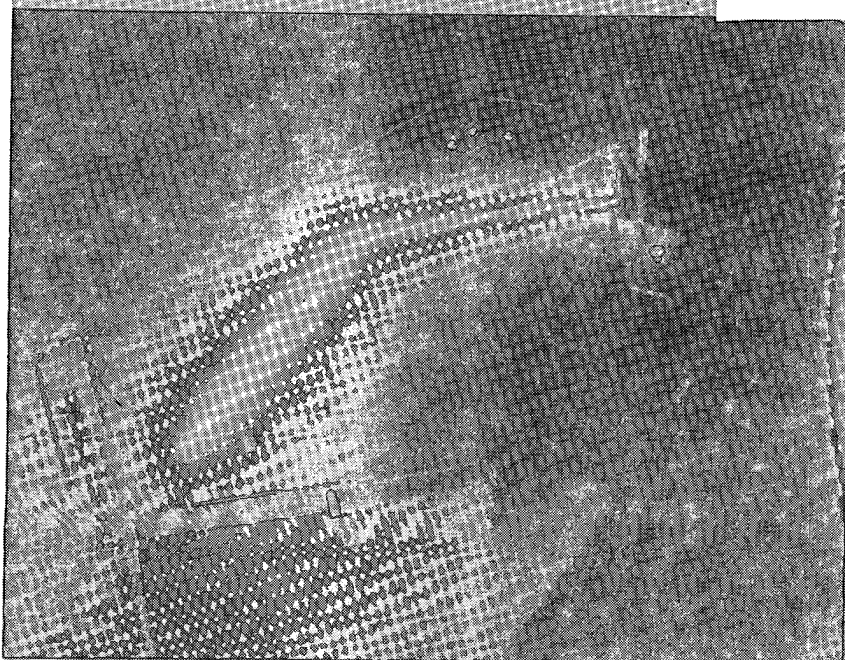


Photo 6-3.

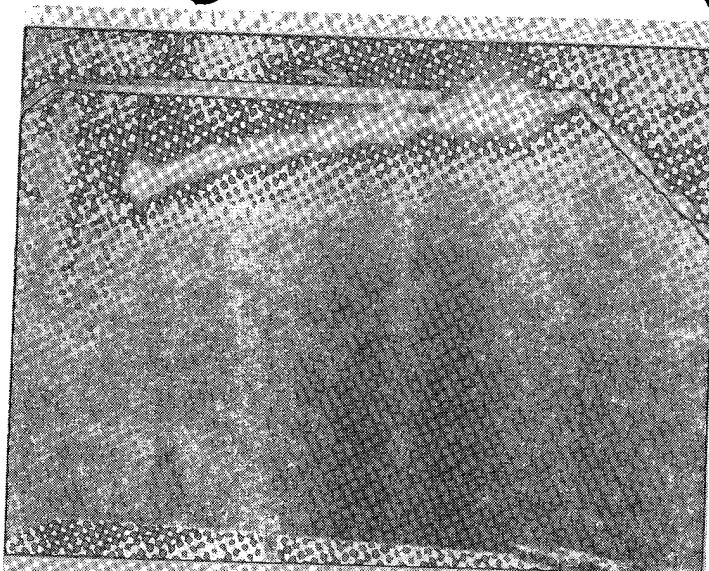


Photo 7-1. Run 7.

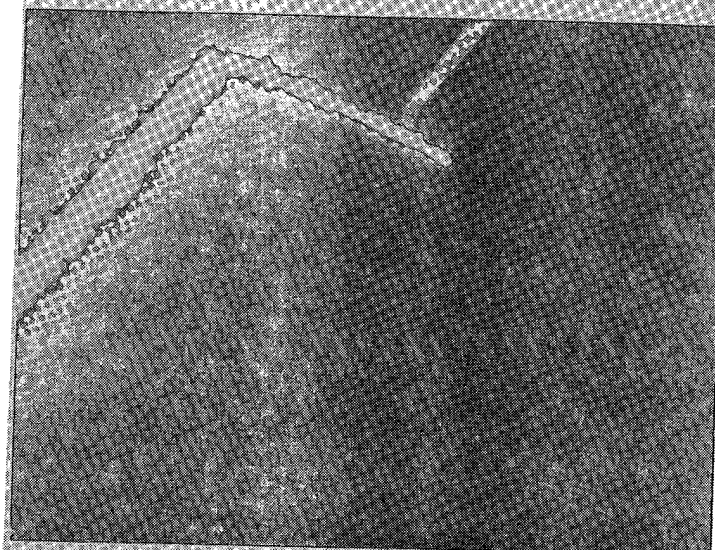


Photo 7-2.

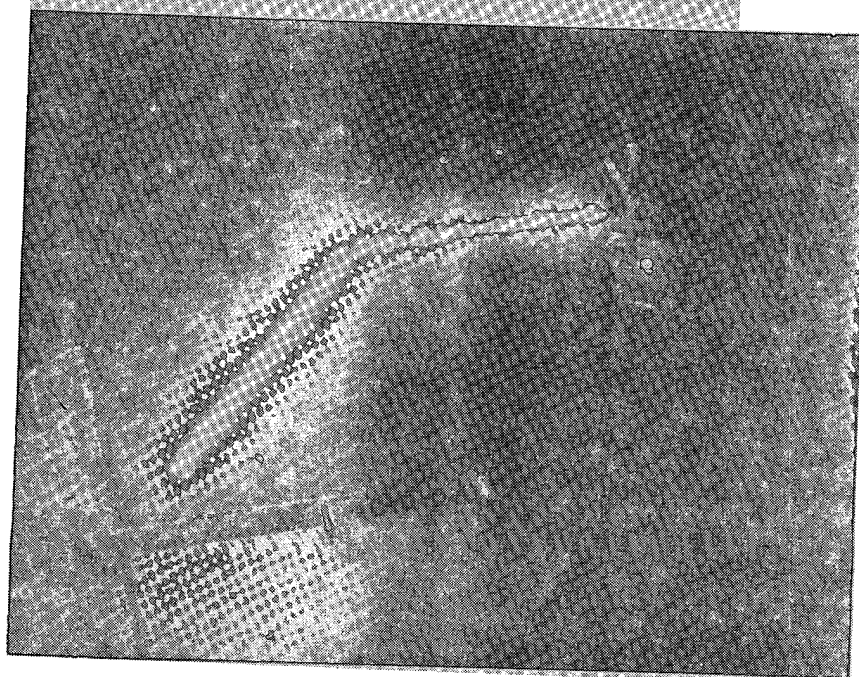


Photo 7-3.



Photo 8-1. Run 8.



Photo 8-2.



Photo 8-3.



Photo 9-1. Run 9.  
L.E. tapes removed.

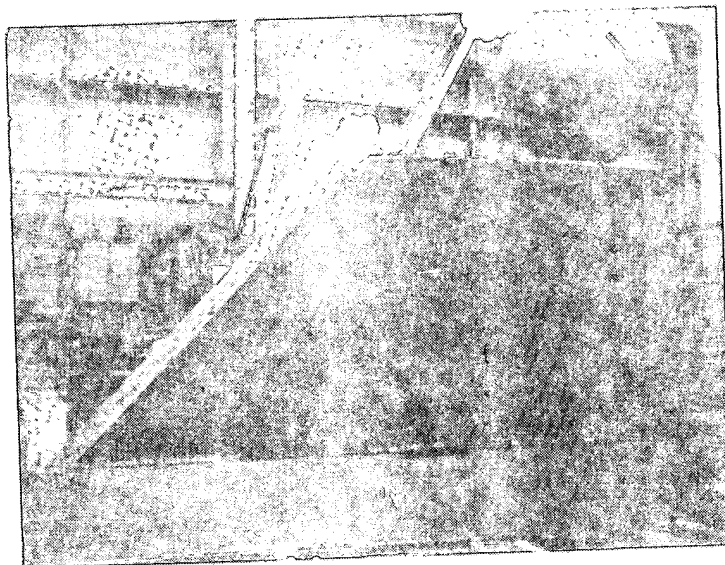


Photo 9-2.

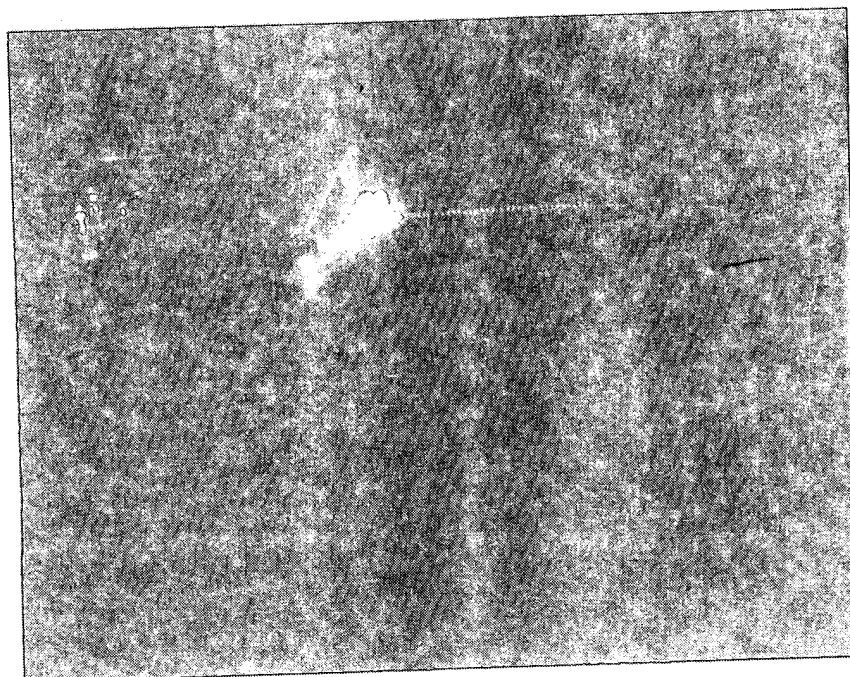


Photo 9-3.

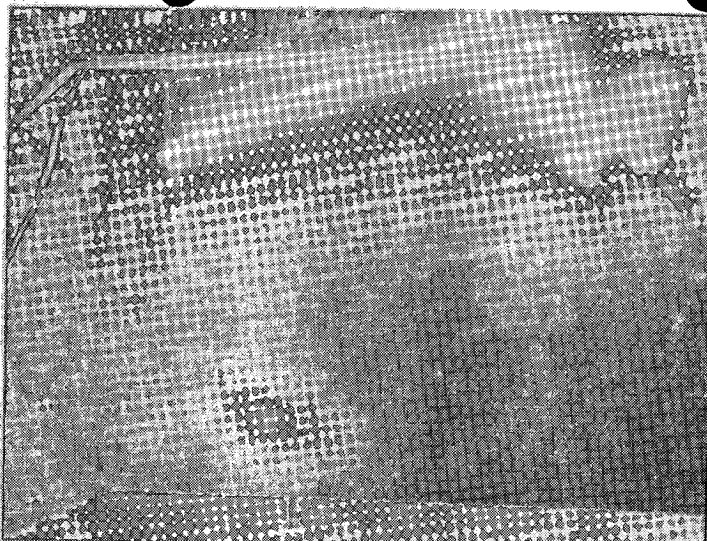


Photo 10-1. Run 10.

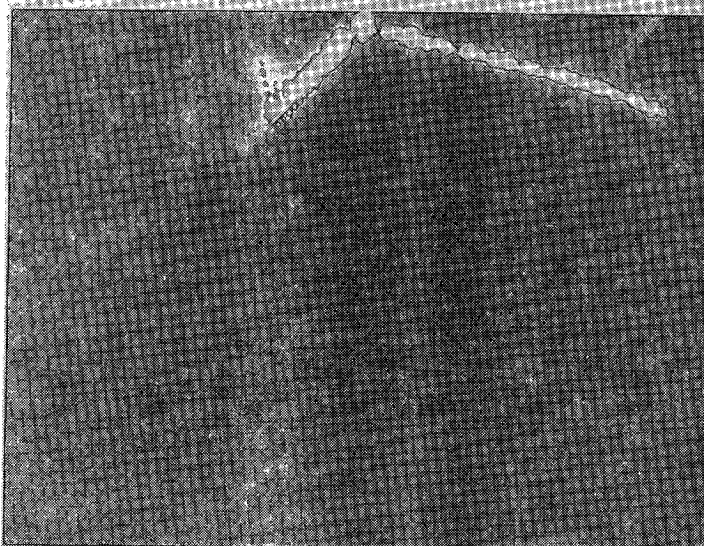


Photo 10-2.



Photo 10-3.



Photo 11-1. Run 11.  
Tape along top partially  
removed.

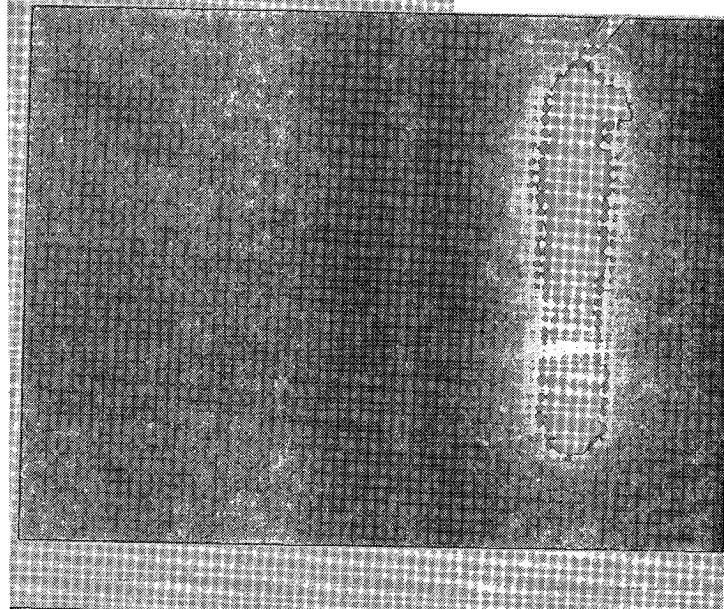


Photo 11-2.

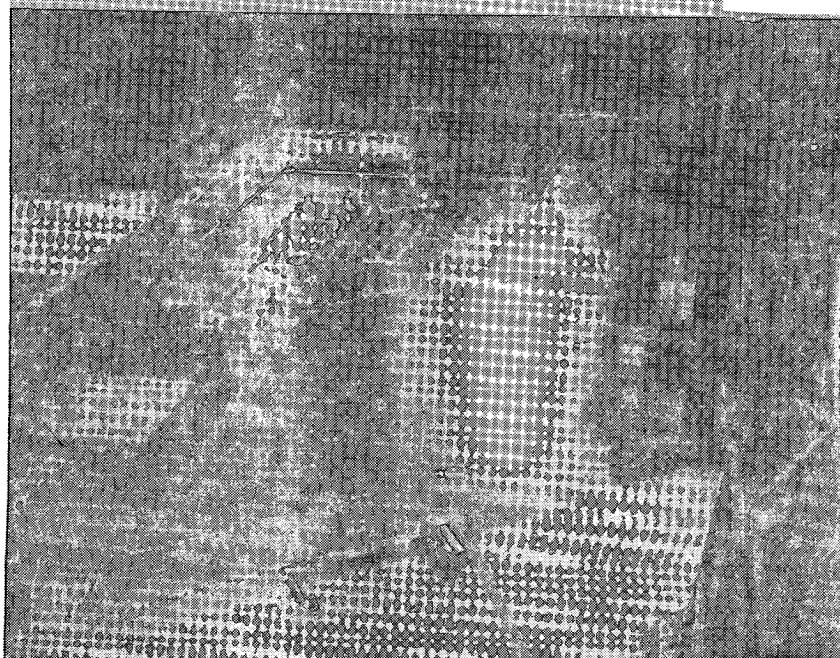


Photo 11-3.



Photo 12-1. Run 12. See tapes removed.



Photo 12-2. Puffs of smoke above post area locate missing jo-bolts.

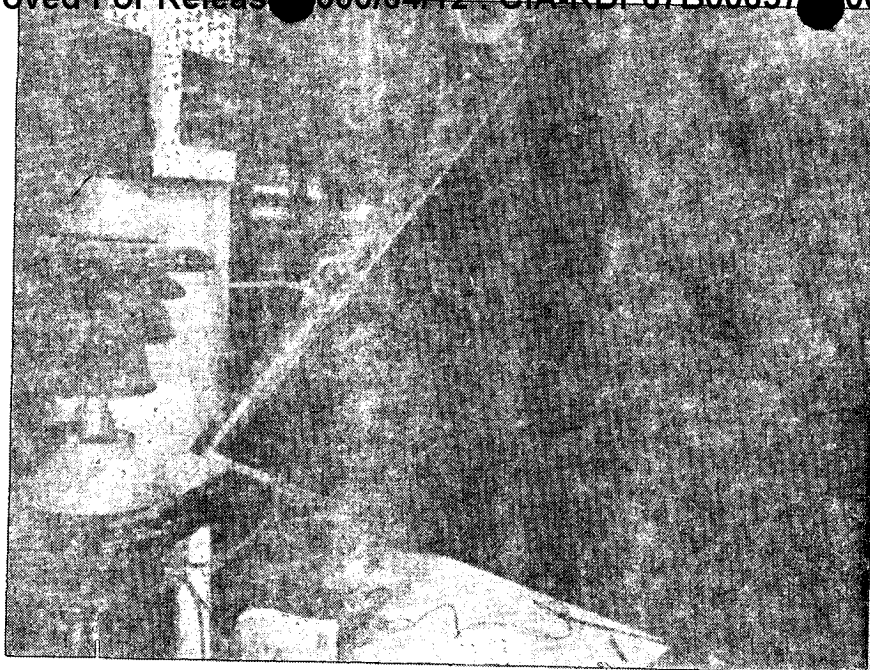


Photo 13-1. Set-up  
for Run 13. Note  
clamps and tapes.

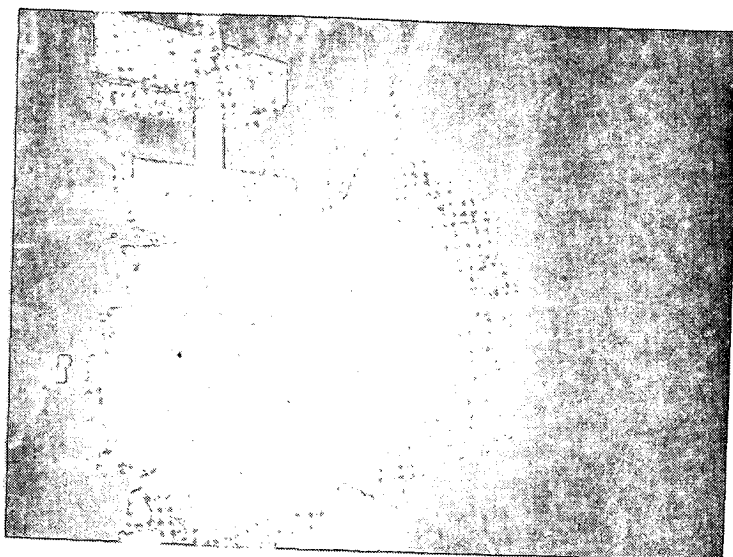


Photo 13-2. Run 13.



Photo 13-3.

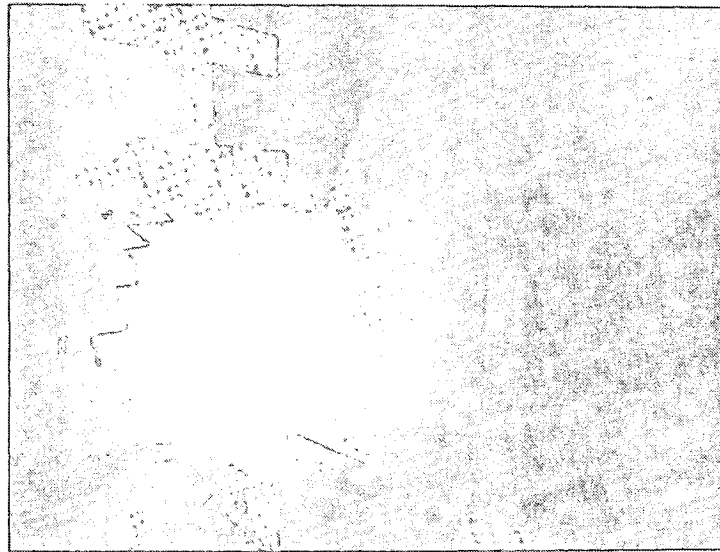


Photo 14-1. Run 14. L.E. section of tapes used.



Photo 14-2.

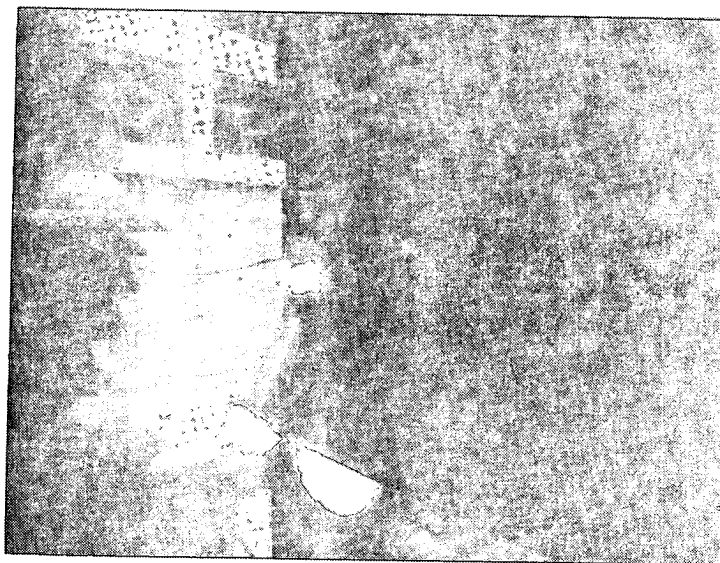


Photo 15-1. Run 15. L.E. tapes off for run.

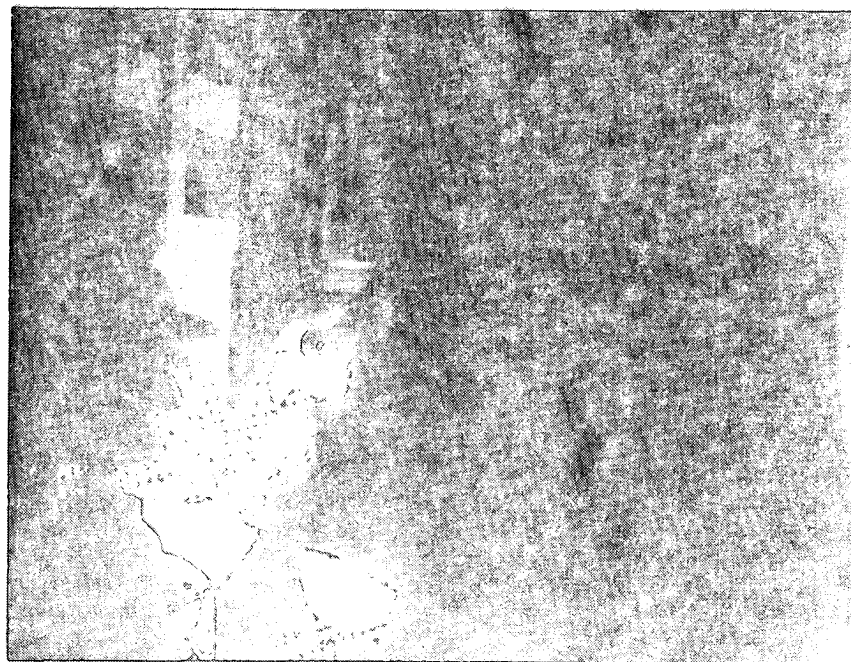


Photo 15-2.

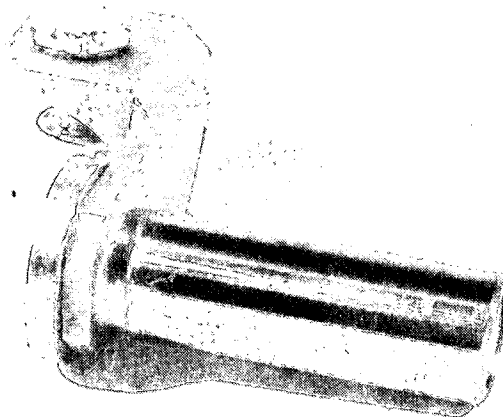


Photo A -Rudder gudgeon arm to actuator link pin after second series of tests. Note pitted area.

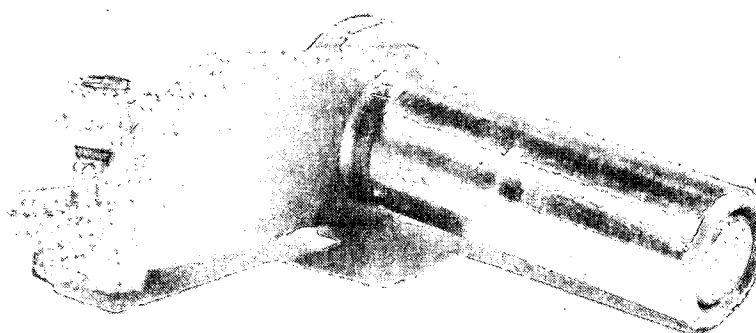


Photo B -Note pitted areas on link pin.

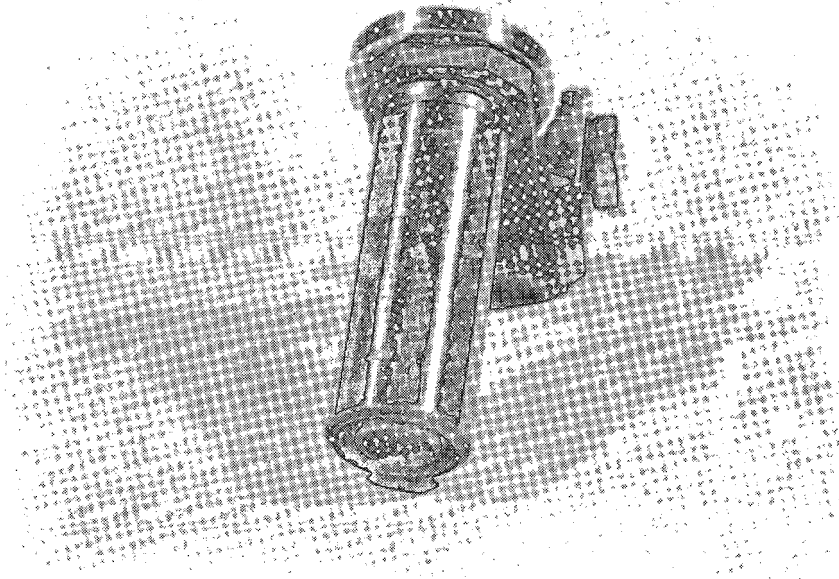


Photo C -Additional pitted area on link pin. The pin had to be forcibly removed from the actuator link spherical bearing after completion of the test.